Historic, Archive Document

Do not assume content reflects current
scientific knowledge, policies, or practices.

Reserve
A58
F763M

UNITED STATES DEPARTMENT OF AGRICULTURE

FOREST SERVICE

MOTOR GRADER TEST

Report of

Caterpillar Grader - Model 12

San Bernardino National Forest

January 23 - March 15, 1950

by

Division of Engineering

and

Arcadia Equipment Development Center

Region 5 - Forest Service

U. S. Department of Agriculture

LIBRARY
RECEIVED
MAY 13 1957
U. S. DEPT. OF AGRICULTURE

UNITED STATES
DEPARTMENT OF AGRICULTURE
LIBRARY

Reserve
BOOK NUMBER A58
F763M
920571

MOTOR GRADER TEST

Report of

Caterpillar Grader - Model 12

San Bernardino National Forest

January 23 - March 15, 1950

by

Division of Engineering

and

Arcadia Equipment Development Center

Region 5 - Forest Service

U. S. Department of Agriculture

TABLE OF CONTENTS

Subject Heading (cont.) | Page

Tables and Figures (Cont) Page

ABSTRACT

This report covers the Field Testing of the Caterpillar Model 12 Grader in an effort to evaluate its ability to operate over Forest Service Roads and Truck Trails.

No important difficulties or major failures were encountered and, although in the consensus of observers the unit was not considered the best of those tested, it was able to perform all of the required tests in a satisfactory manner.

Accordingly the Caterpillar Model 12 Motor Patrol Grader is considered acceptable and capable of completing satisfactorily the normal construction and maintenance work encountered in Forest Service operations.

INTRODUCTION

The grader test described in this report is the result of an effort on the part of the Division of Engineering to determine the adequacy of commercial units offered on bid invitation to perform in accordance with the rigid requirements of the field. This report is on one unit of the Motor Grader Test Project conducted on the San Bernardino National Forest, January 23 to March 15, 1950.

Originally scheduled for two units, the project was expanded at the request of manufacturers to include five companies and five graders ranging from the 22,000 lb. to the 27,000 lb. classes.

This is one of the individual reports prepared for each of the five graders tested. The results of the entire test project are summarized in a composite In-Service, Confidential report which includes a more general analysis and encompasses a wider scope in objectives.

The actual field testing of the graders was divided into two major sections (1) physical characteristics, and (2) field performance.

The first section, referred to as the "flat land" test, consists essentially of observations as to physical design characteristics. This includes such items as clearances, blade maneuverability, turning radius, observations on operational features, visibility, operation of controls, and other such data as would be apparent from a detailed inspection of the machine.

The second section consists of a series of field tests designed to simulate the various field operations normally encountered in routine truck trail maintenance on the National Forests. Such operations as bank sloping, drainage dip construction, three-pass road maintenance, finish grading and several others are included to establish the field operation characteristics of the grader tested.

Every effort has been made to assure comparable test conditions for all graders. Standard procedures were devised, quantities and distances measured, and particular attention paid to soil conditions. Operators were given an instruction period prior to test and allowed to use the machine until such time as they were considered competent by company representatives or, in their absence, road foremen skilled in the use of patrol graders. Company representatives were encouraged to request re-runs where they felt conditions adverse or their machine capable of better performance.

Caterprillar Grader

The grader furnished for the test was a Model No. 12, manufactured by Caterpillar Tractor Company of Peoria, Illinois. The unit was rated heavy duty, tandem drive, with leaning wheels and full revolving circle. It was equipped with cab, scarifier, and oversized tires on the front wheels. The grader was powered by a 100 hp Caterpillar diesel engine.

Figure 1. Caterpillar Grader - Model 12

DESCRIPTION OF TESTS

Section 1

Flat Land Tests

The first phase of the "flat land" test was the obtaining of data covering weights, dimensions, clearances, engine data, fuel requirements, and the other facts concerning the machine as usually given on manufacturers' specification sheets. Data taken from specification sheets and from the inspections are tabulated for comparison and shown as columns 1 and 2 of Table 1, Test Results Section of the report. In most cases the data agreed with that of the manufacturer but in a few instances notable variations were obtained.

The second phase of the "flat Land" tests consisted of an appraisal of the other physical characteristics of the machine as applied to its various functions. The following tests were performed:

I. <u>BLADE OPERATION</u>

The purpose of this test was to determine the maneuverability of the blade and time required for movement from one position to another.

Equipment used consisted of protractor, tape, plumb bob, stop watch, straight edge, still and movie cameras.

The machine was set on a flat concrete slab. Three reference lines were established; one at the machine fore and aft center line; and one on each side of center, running from the inside of the front tires to the inside of the rear tires. All measurements taken were from these reference lines. Center position of the blade was established as that condition at which, with the blade touching the slab, the blade and circle were centered with the machine. Normal position of the blade was established as that position of the blade in which the machine could operate most advantageously with no change in lift arms or linkage. One cycle of blade circle operation was defined as 360° in the case of machines with full revolving blade, or in case of machines not full revolving the maximum degrees of turn of the blade between obstructions.

A. <u>Operation of Circle.</u> Measurements of time and angle of cycle were taken. Observations were made regarding possibility of damage to parts of the machine by operation of the blade.

B. <u>Locking Devices.</u> Observations regarding the presence or absence of circle locking devices, location, and whether or not they could be considered positive were recorded.

C. Bank Sloping Positions. Starting from centered and normal operating position, the blade was moved to maximum bank sloping angle without moldboard shift. Height of blade tip above ground, bank slope angle, position of heel of blade on ground with respect to the tire reference line, and time to shift to this position were recorded.

The moldboard was then shifted for maximum reach and the blade was set at $1\frac{1}{2}$:1, 1:1, 3/4:1, $\frac{1}{2}$:1 and 1/4:1 bank sloping positions. Height of tip of the blade above ground and position of heel of the blade with respect to the tire reference line were recorded. The time required to shift from blade centered, normal operating position to the maximum bank sloping angle was recorded. Still pictures of each bank slope position were taken.

D. Side Shift. The distance the blade could be moved to right and left of centered position, with and without manual moldboard shifting, was measured. The time required for each operation was also recorded. In all cases distances were measured with the cutting edge of the blade resting on the concrete slab. The crew to shift the moldboard manually was limited to the operator and one helper.

E. Blade Lift. With linkage set for normal operation position, measurements were made and time recorded for movement of the blade from ground level to maximum lift position, and also maximum depth below ground, using a pit for this purpose. The number of holes on lift links and the distance of possible adjustment was recorded.

Starting with blade and circle in center position and at right angles to center line of machine the maximum blade lift angle, both right and left, was measured. Links were adjusted as necessary but the blade was not rotated on the circle for this operation.

The height of the lowest point of the circle with the blade at ground level was measured.

F. Blade Reverse. Ability to reverse the blade was recorded. This test concicted of setting the blade at 45° for casting material to the right, then turning blade for backing up, so as to continue casting material in the same direction.

G. Pitch Positions. Information obtained on pitch positions was as follows - number of notches, total adjustment distances and the degrees from the vertical both plus (top ahead of bottom), and minus (top behind bottom.)

H. Visibility. With the blade centered and at 45°, in both right and left positions, visibility of blade and front wheels was appraised from still photos taken from normal sitting positions showing view to right, left, and straight ahead. This procedure was repeated for visibility from a standing position.

Rear view visibility was also noted, with still pictures recording actual views.

II. WHEEL LEAN

The purpose of the test was to determine the degree to which the wheels could be leaned for turning and for resistance to side thrust in operation.

The degrees of lean, both left and right, were recorded, and still shots were taken showing angle as indicated by large protractor.

III. GRADER GROUND CLEARANCE

The purpose was to determine ability of the grader to clear windrows, rock and obstackes which might be encountered either in forward or reverse operation.

With wheels in a vertical position measurements were taken between lowest projections and the ground, behind the blade, and ahead of blade, the latter being limited to 8 inches on either side of center of the front axle. Particular attention was paid to the possibility of damage to steering geometry if it was the lowest projection.

With wheels at maximum lean, measurements were taken in the same manner.

IV. WIDTH OF FRONT TREAD

To determine tread width of graders equipped with oversize tires in front, measurements were taken from center to center of tires, at point of ground contact.

V. SERVICING REQUIREMENTS.

The object of these observations was to determine the time consumed and materials necessary in servicing the equipment.

The number of grease fittings needing daily and weekly service were counted, and time for each service was recorded by equipment service men. Also recorded was the personnel necessary to do a grease job, lubricants and fuel used and types recommended by the manufacturers.

VI. TIRES AND RIMS

To determine adequacy and safety of this equipment, data were recorded regarding ply, size, number, and manufacturer of tires; type of rim and rim association number. At the end of the test, cuts, breaks and wear were recorded, giving reasons when possible. Still pictures were taken to show condition of tires.

VII. TANK CAPACITY

The purpose of this test was to determine ability of the grader to operate for one 8-hour shift with out requiring additional fuel.

Information recorded included factory specification on consumption, factory specification on tank capacity, hourmeter check, amount of fuel supplied, and whether or not eight hours operation was obtained from a full tank.

VIII. REMOVAL OF WINDOWS, DOORS AND CAB

The object was to determine the ease with which doors, windows (windshield) and cab could be removed.

The test consisted of determining if windows, doors and cab were designed for removal, and estimating the time necessary for each operation. The major portion of data were obtained from Forest Service shop personnel and manufacturers.

IX. LIGHTS

The purpose of this test was to determine the adequacy of lights for night operation and travel.

Intensity of the lights was measured by a Weston meter at a distance of three feet. The source of electricity; whether generator, battery or magneto, was recorded. The location of lights, provision for adjustment, and adequacy of protection were noted.

X. ENGINE STARTING

The purpose of these observations was to determine the ability of the engine to start under field conditions.

Time for at least four different starts was determined by a stop watch. Temperature, humidity, whether the engine was hot or cold, type of starting and factory recommended sequence were recorded.

XI. OPERATION OF CONTROLS

The purpose of this test was to determine the adequacy of grader controls.

Information obtained included accessibility, response, ability to vary speed of control action, operation of any two controls at one time, and ease of gear shifting.

XII. TURNING RADIUS

It was desired (1) to determine the minimum circle in which the grader could turn, both right and left, and the road width necessary to do so, and (2) to determine the ability of the grader to turn by backing around in confined areas.

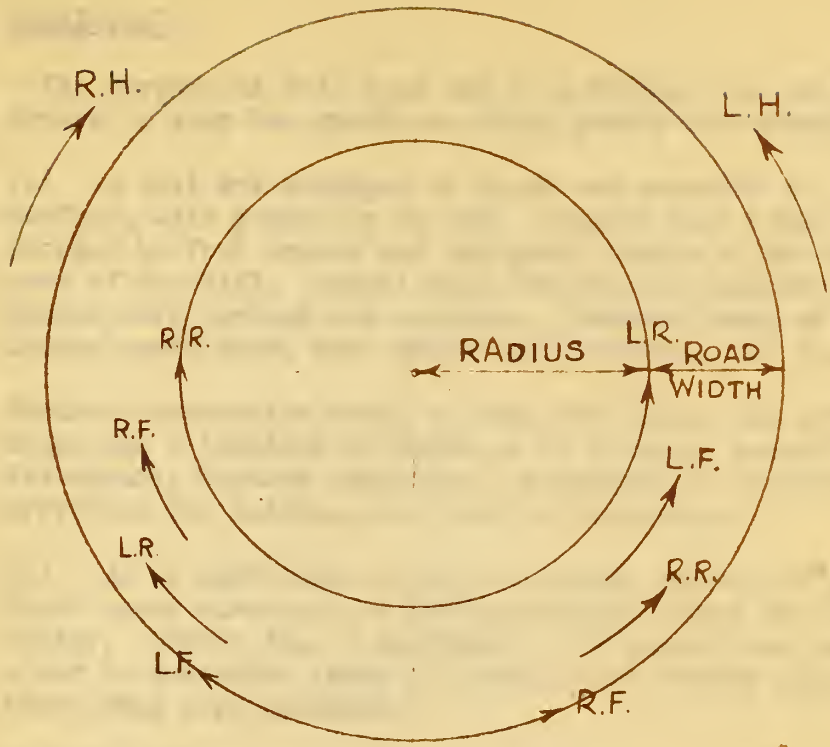
(1) The grader was turned to maximum, and driven to complete a 360° circle, in both right and left direction. The average diameter across the inside tracks was determined by a series of cross-diameter measurements from which the radii were computed.

A second set of measurements was taken across the tracks made in the turning process, and the average taken as the road width necessary for the minimum turn. (Refer to Fig. 2 for sketch.)

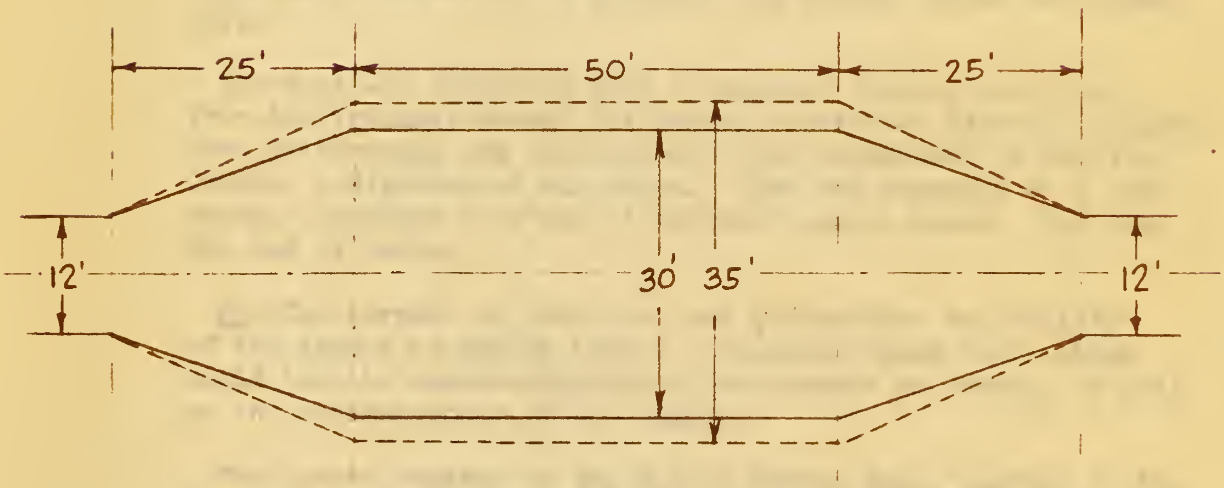
(2) A test area, simulating a turnout on a mountain road, was sketched on a paved area with chalk. The road width approach was 12 feet, tapering to 30 feet at a distance of 25 feet. The 30-foot section extended for a distance of 50 feet.

Operators were allowed to practice on the site so that only maneuverability of the machine was reflected in the test.

The object was to enter the area, turn around with the minimum number of backups, and drive out, keeping within perpendicular limits as designated by the sketched lines. A second set of lines was drawn with a 12-foot road and 35-foot turnout. Separate tests were conducted and results recorded for the 30-foot and the 35-foot width sections. (Refer to Fig. 2 for sketch.)



TURNING RADIUS TEST



TURN AROUND TEST

FIG. 2

XIII. BRAKE TEST

The purpose of this test was to determine the ability of the brakes to stop the grader on steep grades and highways.

(a) A hill was stripped of brush and prepared to a compact surface, with grades up to 49%. Graders were required to be stopped by foot brakes and emergency brakes on the steepest part of the hill. Actual roll forward and backward after brakes were applied was measured. Maximum grade on which brakes would hold, both uphill and downhill, was recorded.

Further information noted on both foot brake and parking brake was - location of drums as to 2-wheel, 4-wheel or driveshaft; whether mechanical, hydraulic or electric; provision for holding, and ease of adjustment.

(b) As an additional check on braking ability of the grader, brake tests were made on level pavement, using the AAA brake tester, (Refer Fig. 1 Appendix.) The grader was paced by a car to determine speed of travel, and braking distances for three runs were averaged.

XIV. WALKING TEST

This test was divided into two parts, the first conducted on a paved highway and the second on a truck trail.

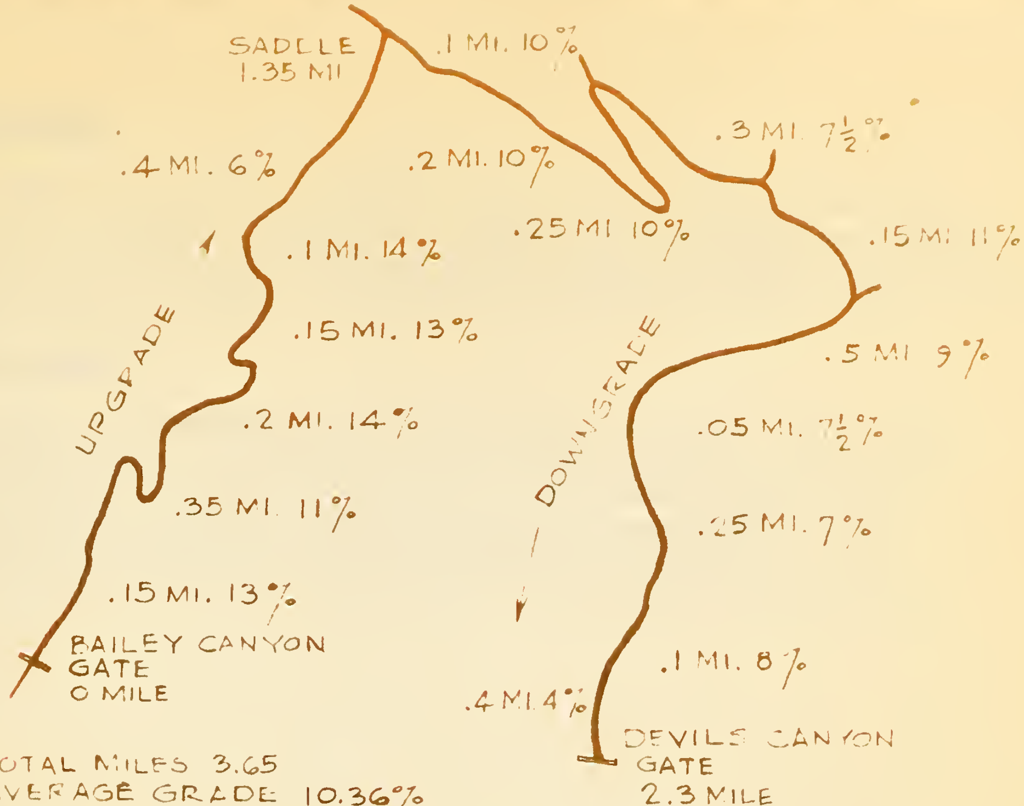
#1. The object in conducting this test was to determine the speed with which the grader could safely travel the highways.

The test was conducted over a measured course, starting from the Triangle Gravel Pit scales, where the official weights were determined, and terminated at the campground at Devil's Canyon, a distance of 6.1 miles. Time was recorded by a stop watch. Machines were run at governed engine speed. See Fig. 3 for map of route.

#2. The purpose of this test was to determine the ability of the grader to safely travel a measured truck trail which would tax the maneuverability of the grader on curves, as well as the maximum power of the engine.

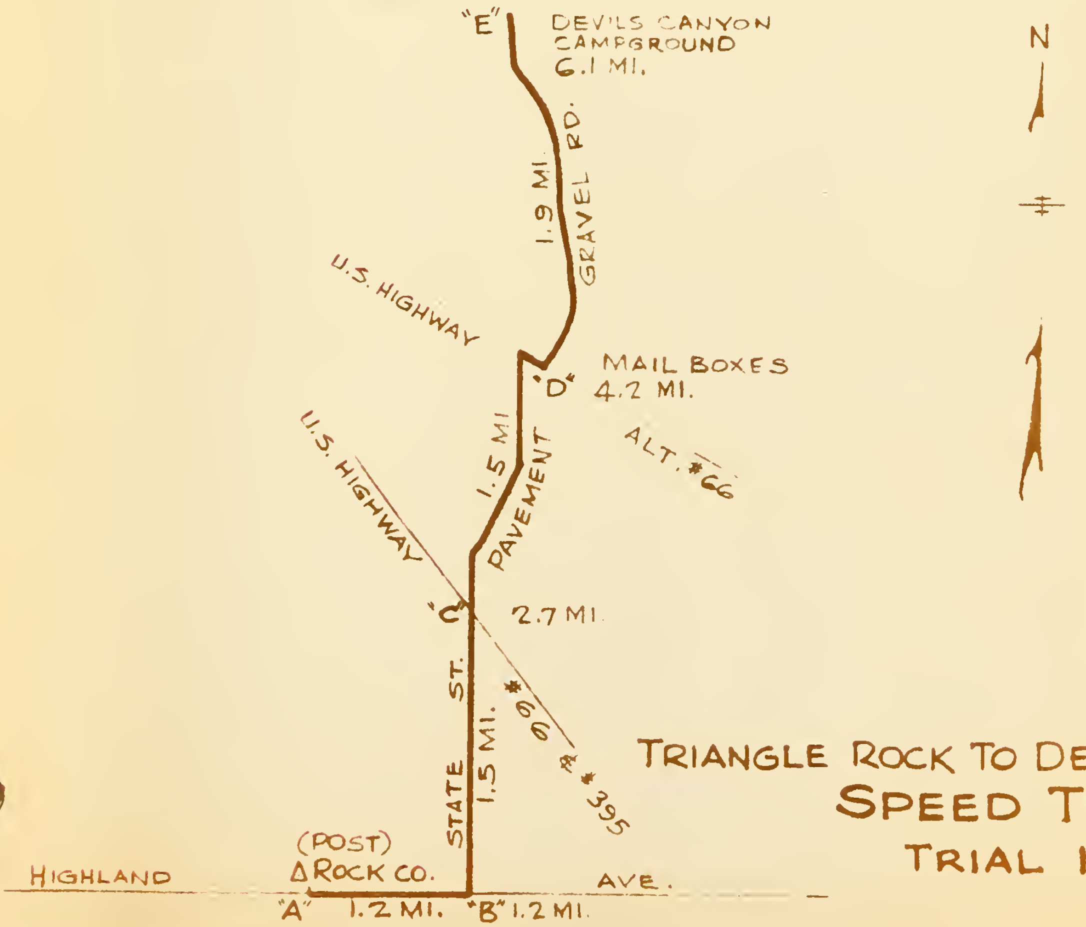
The course started at the Bailey Canyon gate, upgrade to the saddle at the junction of Devil's Canyon truck trail, thence downgrade to Devil's Canyon gate, a distance of 3.65 miles.

Data recorded were time for uphill and downhill trips, grades, and road condition. See Fig. 3 for map of route.



TOTAL MILES 3.65
AVERAGE GRADE 10.36%
1.35 MILES UPGRADE (AV. 11.83%
2.30 MILES DOWNGRADE (AV. 8.89%
1 CURVE LESS THAN 35' RADIUS

BAILEY CANYON WALKING TEST -TRIAL 2



TRIANGLE ROCK TO DEVILS CANYON SPEED TEST TRIAL 1

FIG. 3

XV. BREAKDOWNS

While not in the form of a test, an informational list was set up as follows: breakdowns, description of breakdowns, photographic record of each, cause (whether design weakness or accident), facilities to repair, availability of parts, and time lost.

XVI. FINAL CHECK

After the grader had been put through the field tests of Section 2, it was returned to the "flat land" slab, thoroughly cleaned and carefully examined for all cracks, breaks and bends which were not evident as definite breakdowns. Each defect was described and photographed for permanent record. Pictures were taken of the tires to record wear and injuries.

DESCRIPTION OF TESTS

Section 2

Field Test

Field performance tests were as follows:

I. SLIDE REMOVAL

The purpose of the test was to observe the ability of graders to surmount obstacles, such as slides commonly encountered in road maintenance.

Slides occur frequently on roads in steep terrain. If the motor patrol can handle the occasional slide and thus save importing a bulldozer, a considerable saving will result.

A slide of designed shape comprising approximately 125 cubic yards was built by a tractor, avoiding compaction of material as much as possible. Dirt was allowed to accumulate on the downgrade (or approach) side at its natural angle of repose, which was approximately 70%. Boundaries were established by means of stakes simulating a perpendicular bank beyond which a wheel under power was not permitted. Refer to Fig. 4.

Fig. 4. Test Slide

The test machine was required to climb over the slide in order to be in a position to attack the dirt removal task on a downhill basis.

Test conditions were recorded by still shots and progress during the test by movies. Information recorded consisted of - size of slide and time required to climb over, operator sequence and method of attack.

Since more than one machine was tested at this site, after the machine surmounted the slide, no further dirt was removed. The slide was then reconstructed to original size and shape.

II. IN-CURVE

The purpose of the test was to measure the ability of the grader to maneuver on a short radius in-curve.

Conditions of the test: The situation simulated was the wash-out on a canyon crossing, the outer portion of the road being completely gone and the inner portion defined by vertical walls. It was required that the grader was required to travel the curve, using the minimum road width. See Fig. 5 for details and sketch of test layout.

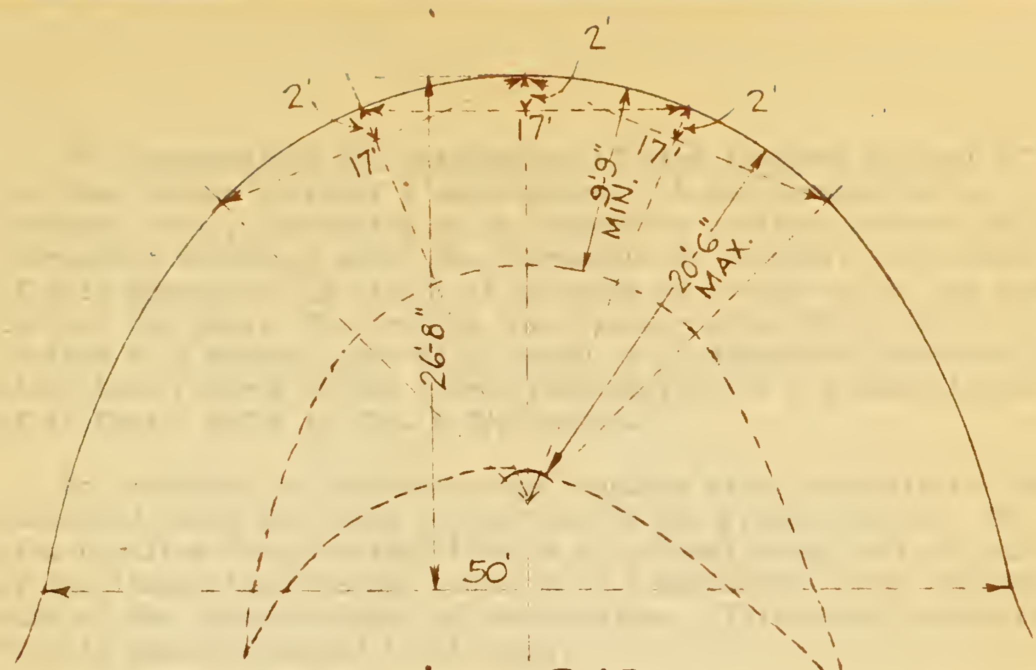
This condition results frequently after severe storms in rugged country. Ability of a particular machine to handle these situations would save much expense in importing a bull dozer for the operation.

Performance was recorded by use of movies and still pictures. The maximum width of road needed as measured from the inside tire track to the simulated perpendicular wall was recorded.

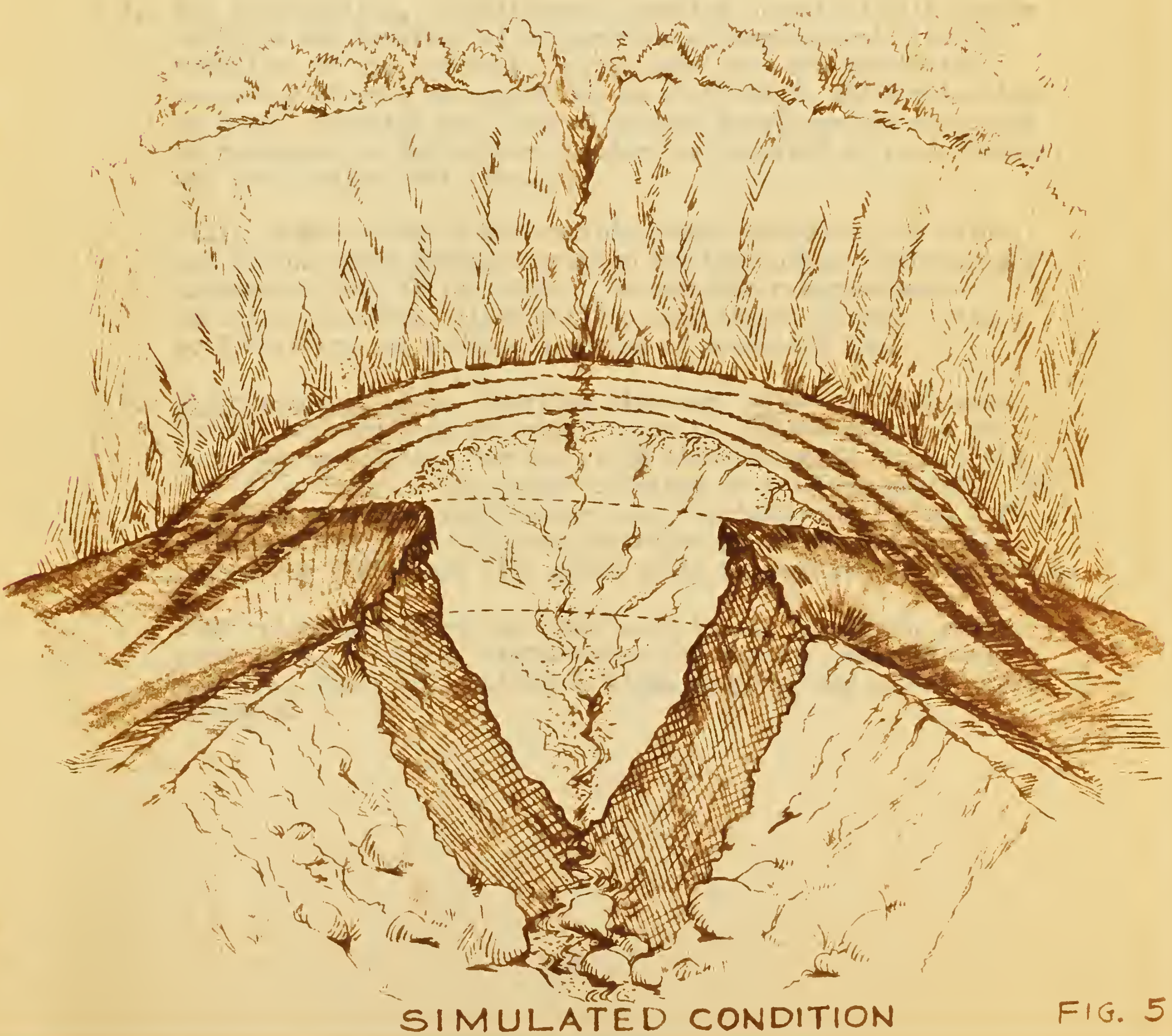
Since ability of operator affects the time required, re-runs were allowed if operator thought he could improve the performance. Regardless of time consumed, operator ability was evaluated in an attempt to determine machine performance, analyzing reasons for such.

III. GRADING OF DIPS

The life and useability of a road depends to a considerable extent upon the proper functioning of the drainage system. Grading of dips is one of the most important operations of a grader on roads where intercepting drainage dips are used.



INCURVE



SIMULATED CONDITION

FIG. 5

The construction and maintenance of dips involves several of the functioning parts of a motor patrol. A dip consists of an involute curve, descending on an increasing vertical curve with an increasing outslope, until the depression if reached. The bottom of this depression is placed at an angle of 45 degrees to the center line of the road. The profile then rises rapidly for a distance of 15 feet to a summit, also at an angle of 45 degrees to the road center line, then returns to the normal road profile in a second distance of 15 feet. Refer to Fig. 6 for sketch.

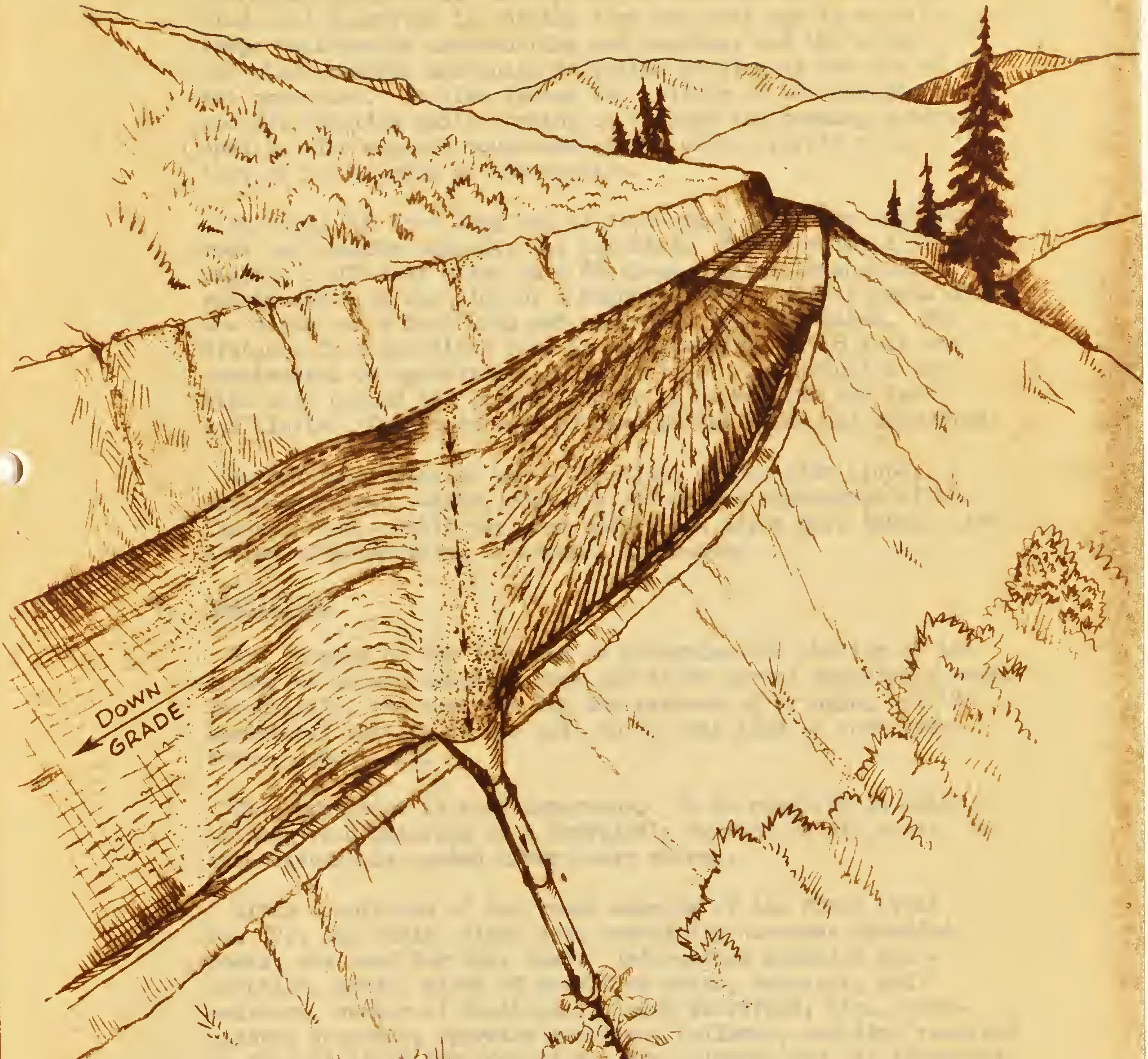
To construct or maintain a dip requires blade manipulation both above and below the plane of the base of the grader wheels. It also requires blade manipulation in a vertical plane to take care of the increasing outslope and also in a horizontal plane to take care of the changing angle of the outslope. This second manipulation is usually handled by steering.

A. New Construction. Conditions: Operator practiced with grader until he was familiar with operation of machine and also the technique of tip construction. Stakes were set indicating beginning of cut, bottom of dip on a 45° angle and termination of berm. Operator was allowed as many passes as was necessary to construct to the proper standard as required by road foreman, who was judging this test.

Still pictures were taken at side before operation and after, and movies taken during operation for the purpose of analyzing maneuverability of the blade. Information recorded was - location, material, difficulties, operational sequence, time, soil moisture and foreman's rating of completed job.

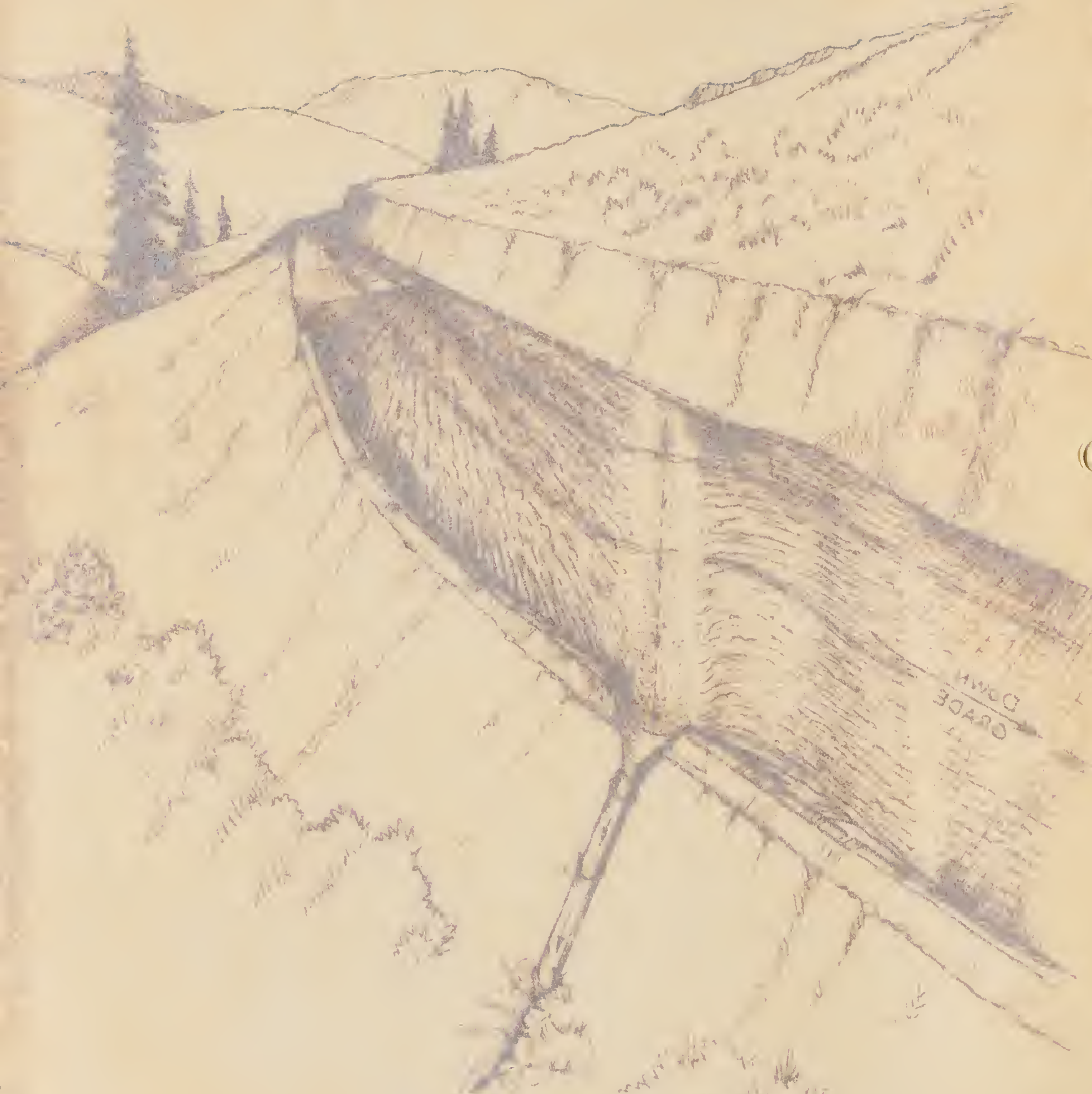
B. Maintenance of Dips. Existing dips were selected which were in need of reshaping and sluff removal. Motion pictures of operation were taken for analyzing blade response to controls and the ability of the blade to follow an existing profile. At the same time observations were made to determine if the lift mechanism range was adequate for below grade extension while possessing sufficient lift above grade to complete the operation.

Still pictures before and after were taken. Location, grade, road width, material, difficulties and reasons, operational sequence, time, soil moisture, blade response and control were recorded.



INTERCEPTING DIP

FIG. 6



INTERCEPTING DIP

FIG. 6

IV. DITCHING

The purpose of this test was to determine the ability of the machine to function under difficult conditions involving extremely heavy work. The operation involved the use of the blade and scarifier in cutting dirt and rock and in removing large boulders by undercutting and pushing, and the blade and blade control mechanism in finish grading at the end of the operation. It also tested the ability of the machine to provide traction while working on a slope and pushing material uphill. The general toughness of the whole operation was a test of the stamina of the machine.

An area, 200 feet long and 32 feet wide, which was high in rock and boulder content, was selected. Test consisted of digging a 200-foot ditch on a 6% slope similar to shoulder construction on one side of a highway. The vertical depth of the ditch was 3 feet with cut bank on a 3/4-to-1 slope. The distance from the ditch line to the shoulder was 16 feet and constructed on approximately a 4:1 slope. All material was side cast beyond the 16 foot width, or beyond the 200 foot end limits. Operators were allowed to use blade and scarifier.

Information obtained was - location, grade, side slope, material, depth, width, distance, time, and appearance of the finished job. Still pictures before and after were taken, also movies of interesting or unusual incidents.

V. SCARIFYING

The purpose of the test was to determine the ability of the grader to loosen imbedded rock and to do normal scarifying work. Essentially, the test was for the purpose of bringing out the structural ability of the unit to do this kind of work under severe conditions.

This operation is very important. It is required in maintaining road material or a travelable surface on all roads, and is particularly needed after heavy storms.

After completion of the rough shaping of the ditch (Test No. IV), the inside slope area containing numerous imbedded rocks, was used for this test. Information recorded was - location, grade, width of scarifier swath, material, soil moisture, number of teeth used, depth scarified, time, operational sequence, operator reaction, failures, and time required to install teeth for operation. Time element was not important except to require operation at a reasonable speed. Still shots, before and after, and movies were taken.

VI. BANK SLOPING

The purpose of this test was to determine the ability of the graders to side-slope banks at any required slope from $1\frac{1}{2}$-to-1 to 1/4-to-1.

This operation involved the use and adjustment of the control arms, the use of the circle, and general manipulation of the circle and arms assembly.

Sections of roads 500 geet long were selected in which banks at least 10 feet high existed, and included in-curves, out-curves and tangents.

Information recorded was - location, grade, material, distance, time, maximum height of cut, analysis of finished job, difficulties, and operator reaction. Still shots were taked of grader in position, and of road before, during, and after. Short movie sequences were taken to record the operation.

Bank sloping on Forest-Service work is done largely on reconstruction or heavy maintenance work. Although it does not involve a very high percentage of total volume, the occasions of use require a highly maneuverable blade assembly.

VII. DRIFTING

The purpose of this test was to determine the ability of the grader to end-haul material. The operation involves the size, design and pitch of the blade controls.

Drifting is required continually in normal maintenance operations to remove slides, fill washouts, and restore surfacing.

Material for drifting operation was taken from a low cut bank extending 100 feet, moved across a 25-foot area, and placed in an area 75 feet long and 12 feet wide, to a depth of .6 of a foot, forming a finished road bed. At the end of each pass, grader with blade lifted returned to the far end of cut bank section.

Data collected included - location, distance, grade, material, angle of blade, pitch of blade, estimated yardage, material lost or picked up enroute, time, and operator reaction.

Time element was very important in this test since it reflected balance of power and blade size, ease and dexterity of blade movement and time consumed in shifting gears.

Still pictures were taken to show before and after operation, also movies to show dirt movement on blade, and amount of material being moved.

VIII. HORIZONTAL MOVEMENT OF WINDROW

The purpose of this test was to determine the ability of the machine to move a windrow of dirt laterally. It involved the size, shape and pitch of the blade, the tractive ability of the machine, and the functioning of the blade control mechanism.

This operation is used in all road mix oiling work and in construction of roads on flat terrain.

A section of road 1300 feet long, with an average grade of 9%, was designated as the test area. A large windrow was formed on one side of the road, and measurements made from established reference points. The grader in four passes was required to move as much material as possible to the opposite side of the road, forming a more or less uniform windrow. Lateral movement of dirt was determined by measurements taken at the reference points, and total yardage figured from cross section measurements taken every 100 feet. The elapsed time for the operation was recorded.

IX. SHAPING BERMS

The purpose of the test was to determine ability of the grader to form a berm 18" high with side slopes $1\frac{1}{2}$:1. This operation is of great importance on all roads using berms as a drainage control feature. This includes most of the road mileage in the California Region.

A section of road between 300 and 500 feet in length was selected and material in existing berm was spread over the road bed. Three passes were then made, ending up with the material forming a uniform berm on the outer edge of road.

Information recorded was - location, grade, material, distance and time. Still shots before, during, and after operation were taken.

X. HILL CLIMB

The purpose of the test was to determine the ability of the machine to climb grades up to 50% in both forward and reverse gears.

The site selected for the test had a runway with an overall length of 300 feet, which started level and gradually sloped up to a maximum of 49%. Graders were required to climb uphill forward and uphill backward, recording percent of grade at the forward point of stalling, if any. The decomposed granite surface of the hill was prepared before each run so no loose material hindered the test.

XI. UPHILL GRADING

The purpose was to determine the ability of the machine to climb uphill and do normal grading at the same time.

Road sections, 500 feet long, in which grades from 10 to 21% existed, were selected. One pass uphill was made.

Information noted was - location, material, soil moisture, grade, time, tendency of machine to drift under load, and appraisal by road foreman as to effectiveness of the work. Still shots before and after, and movies during operation were taken.

XII. ROAD GRADING

The purpose of the test was two-fold; first, to acquaint operator with the three-pass operation in road maintenance and, second, to provide an opportunity for observers to analyze the performance of each grader on a short section of road.

Sections of road 500 feet long were selected which were in need of maintenance, and which included in-curves, out-curves, turnouts and dips.

Operation consisted of three passes: cleaning the ditch of sluff, spreading and removing rocks and smoothing.

Information recorded was - location, grade, road condition as to ruts, amount of sluff, material, soil moisture, distance, time, maneuverability, difficulties, appearance of finished job, and operator's reaction. Still shots before, during, and after operation were taken.

XIII. ROAD MAINTENANCE - LONG SECTION

The purpose of this test was to determine the overall ability of the grader to do all of the important functions of a road maintenance job. These operations include slide and sluff removal, dip maintenance, normal and fine grading, berm construction, and drifting. Bank sloping was not included. Operation was up and down hill and around minimum radius curves (under 35 feet), and involved the use of all grader controls.

This work is the primary purpose for which motor patrols are purchased and constitutes the larger portion of their use.

Sections of truck trail with grades up to 20% and needing maintenance work, two miles in length, were marked by means of flags. Picture stations were marked for the purpose of before and after photographic records which would depict the different functions common to the operations of rock removal, sluff removal, dip cleaning and shaping, and fine grading. Three passes were required.

Information recorded was - location, material, distance, time, amount of work to do in rock, sluff removal, number of dips to shape, and number of minimum curves.

Appearance of the finished job was appraised by engineers and road foremen.

Fine Grading

On the two mile maintenance section an area suitable for fine grading was selected where no appreciable amount of rock was present.

Results of the operation were carefully analyzed for absolute control of the blade, since this test was considered as a measure of the ability of the grader to handle surfacing operations.

Still pictures before and after were taken to indicate the degree of improvement resulting from the operation.

TEST RESULTS & COMPARATIVE DATA

To facilitate comparison and to conveniently tabulate the various date obtained from the test, Table I, Comparative Data, has been prepared.

The date recorded in column one (1) are taken from the manufacturers' published specification sheet and cover the standard production model only.

In column two (2), are summarized the data taken from the "flat land" and "field test" sections of the report. Discrepancies in this column from the manufacturers' ratings as shown in column one (1) may be attributed to definition or deviation from standard on the test machine. Where considered necessary, deviations are discussed under the Discussion of Test Results.

In columns three (3) and four (4) are the data of other graders tested in this class. The intent here is to show the maximum and minimum of the other data collected. It should be noted that the maximum as shown does not necessarily infer the best, particularly where time is involved. Constant appraisal of the item under consideration will be necessary to properly evaluate the tabulated results.

TABLE I

COMPARATIVE DATA

Flatland Tests

Items	Mfg. Spec. Std. Machine (1)	Cat. #12 Test Mach. (2)	Other Graders Tested Maximum (3)	Other Graders Tested Minimum (4)
WEIGHT				
Weight, total	22,200	24,690	27,950	22,560
Weight on front whls.	6,250	7,350	9,350	7,400
Weight on rear wheels	15,950	17,200	19,300	13,150
Blade pressure	---	13,350	18,520	12,300
Scarifier pressure	8,500	8,200	10,460	8,620
DIMENSIONS				
Length overall	25'-2"	25'-2"	27'-0"	24'-3"
Width overall	7'-10"	7'-10"	8'-0"	7'-7-3/4"
Height overall w/cab	9'-10"	9'-10"	10'-8"	9'-8¼"
Height overall w/out cab	7'-5"	7'-5"	8'-8"	6'-10"
Height inside cab	---	69"	75½"	72"
Wheelbase	18'-9"	18'-9"	19'-7"	18'-8"
Tread, front, c.to c. of tires.	80"	79½"	83¼"	79"
Tread, rear, c. to c. of tires	78½"	79"	82"	78½"
SPEEDS				
Min. forward mph	2.3	---	2.6	1.7
Max. forward mph	19.3	---	25.2	15.0
Min. reverse mph	2.7	---	3.7	1.74
Max. reverse	4.1	---	6.13	5.3
Number forward	6	6	8	6
Number reverse	2	2	3	2
ENGINE				
Brake HP	100	100	113	76
No. of cylinders	6	6	6	4
RPM - Governed max.	1,800	1,900	1,990	1,555
CAPACITIES				
Fuel tank (gals.)	60	60	58	45
Cooling system (gals.)	15	15	20	6½
Crankcase (qts.)	23	23	20	16
TIRES				
Size, front	9.00-24	13.00-24	14.00-24	13.00-24
Size, rear	13.00-24	13.00-24	14.00-24	13.00-24
Ply	10 F. 12 R	12	14	8

TABLE I (Continued)

COMPARATIVE DATA

Flatland Tests

Items	Mfg. Spec. Std. Machine (1)	Cat. #12 Test Mach. (2)	Other Graders Tested Maximum (3)	Other Graders Tested Minimum (4)
BLADE ASSEMBLY				
Moldboard - Length width, thickness	12'x24"x3/4"	12'x24"x3/4"	13'x$22\frac{1}{2}$"x3/4"	12'x22"x3/4"
Blade side shift (R&L)	---	---	---	---
(Mfgrs. Rating	36" power oper.	---	71° power oper.	$26\frac{1}{2}$"
Right blade side shift from center position	---	---	---	---
(circle shift)	---	25"	$25\frac{1}{4}$"	$16\frac{1}{2}$"
(circle shift & link adj.)	---	25"	$38\frac{1}{4}$"	19"
(circle, links & moldboard adj.)	---	51"	$62\frac{1}{2}$"	54"
Blade lift above ground Sect. 1 - Test E	18"	$15\frac{1}{4}$"	16"	14-3/4"
Blade depth below ground Sect. 1 - Test E	---	$10\frac{1}{2}$"	$23\frac{1}{2}$"	5"
Pitch positions - number for tilting	13	13	15	6
Max. shoulder reach	88"	$76\frac{1}{2}$"	$88\frac{1}{4}$"	78"
Bank slope angle (Test conditions 1-C-3)	---	$57\frac{1}{2}^\circ$	74°	52°
Circle diameter	$60\frac{1}{2}$"	$60\frac{1}{2}$"	63"	54"
Degree turn blade w/scar. teeth	---	307°	320°	296°
Degree turn w/o scarifier teeth	---	360°	360°	320°
Lifting speed (Approx.)	3"/sec	2.18"/sec	2.37"/sec	0.98"/sec
SCARIFIER V TYPE				
Weight	1,314	1,314	1,47[illegible]	1,300
Swath width	46"	46"	46"	46"
Teeth number	11	11	11	9
Teeth size	1"x3"	1"x3"	$1\frac{1}{4}$"x$3\frac{1}{2}$"	1"x3"
Pitch positions	4	4	5	1
Pressure max.	8,500	8,200	10,460	8,620
WHEEL LEAN				
Max. L	---	20°	$21\frac{1}{2}^\circ$	$15\frac{1}{2}^\circ$
Max. R	---	20°	$22\frac{1}{2}^\circ$	11

TABLE I (Continued)

COMPARATIVE DATA

Flatland Tests

Items	Mfg. Spec. Std. Machine (1)	Cat. #12 Test Mach. (2)	Other Graders Tested Maximum (3)	Other Graders Tested Minimum (4)
GROUND CLEARANCE				
Behind blade) Wheels Vert.	---	$13\frac{1}{2}$"	13"	10-3/8"
Front blade) Wheels Vert.	---	22"	$27\frac{1}{2}$"	14"
Behind blade) Wheels Max. lean.	---	$13\frac{1}{2}$"	13"	10-3/8"
Front blade) Wheels Max. lean.	---	20-3/4"	27"	19"
TURNING				
Turning radius (Inside wheel) R	---	21'-10"	27'-9"	22'-$\frac{1}{2}$"
Turning radius (Inside wheel) L	---	28'-1"	29'-3"	22'-9"
Turn. radius - Ave. inside wheel ÷ ave. road width	---	38'5"	41'-$2\frac{1}{2}$"	30'-6"
Road width to turn R	---	13'10"	13'-5"	8'-0"
Road width to turn L	---	13'1"	13'-4"	8'-2"
Field Tests				
ROAD WIDTH FOR TURNING - NUMBER OF BACKUPS				
35 Foot Road	---	2	4	2
30 Foot Road	---	5	8	3
DIP CONSTRUCTION (Time)	---	27 M. 0 S.	25 M. 23 S.	14 M. 36 S.
DITCH CONSTRUCTION (Time)	---	8 H. 20 M.	11 H. 33 M.	8 H. 58 M.
DRIFTING (Cu.Yds./Min)	---	1.29	1.12	0.97
MOVE WINDROW (Cu.Yds. Feet/min.)	---	107.0	149.0	85.5
SLIDE (climb over in min.)	---	21 M. 59 S.	50 M. 0 S.	15 M. 57 S.
INSIDE CURVE				
Road width needed - Ave. L & R	---	19'-$7\frac{1}{2}$"	19'-$11\frac{1}{2}$"	9'-$7\frac{1}{2}$"
ROAD MAINTENANCE (Miles/Hr.)		0.635	0.59	0.48
BRAKE TEST - 18 mph Cal. Veh. Code Min.	---	32'	38'	15'

TABLE I (Continued)

COMPARATIVE DATA

Field Tests

Items	Mfg. Spec. Std. Machine (1)	Cat. #12 Test Machine (2)	Other Graders Tested Maximum (3)	Minimum (4)
WALKING TEST (1)				
Paved Highway	4.2 Miles	19.9 MPH	24.6 MPH	15.8 MPH
Dirt Highway	1.9 Miles	17.54	16.38	12.35
Total Highway	6.1 Miles	19.1	19.94	14.5
WALKING TEST (2)				
Uphill T.T.	1.35 Miles	6.56 MPH	6.37 MPH	4.49 MPH
Downhill T.T.	2.3 Miles	14.33	16.24	9.13
Total T.T.	3.65 Miles	9.98	8.52	7.70

DISCUSSION OF RESULTS

Flat Land Tests

WEIGHTS

The weight distribution of the Cat #12, as shown in Table 1, was found to conform very closely to that of other tandem graders. Table II-A below shows the maximum deviations from the average of the other tandems to be less than 2.5%.

TABLE II-A -- WEIGHTS

	Cat #12	Average Wt. Other Tandem Graders	Distribution Percent Cat#12	Distribution Percent Other Tandems
Total	24,690	25,850	100	100
Front	7,350	7,810	29.8	30.2
Rear	17,200	18,017	69.7	69.7
Scarifier	8,200	9,163	33.2	35.4
Blade	13,350	13,493	54.1	52.2

This table shows the Cat #12 to be less than average in total weight. However, it was in the intermediate group, since the weight of one machine was some 2,800 pounds in excess of the other tandems.

Weight on front and rear axles, although slightly less than average, were considered in reasonable proportion to the overall weight, using the average of all tandem graders as a criterion.

Weight on the scarifier was less than that of other graders tested in actual pounds, and also in ratio to overall weight. However, this condition was not judged detrimental to work output.

Weight which could be exerted on the blade was sufficient to raise the front wheels from the ground, and represented 54.1% of the total weight of the grader.

Proper weight distribution of some graders was questioned during the field tests because of drifting and loss of traction. After reviewing weights of all graders in the test, it was apparent that horsepower was a factor to be considered along with weight.

Accordingly, an analysis of overall weight per horsepower and drivewheel weight per horsepower was made. The figures provide material for interesting discussion.

TABLE II-B

Weight Horsepower Ratios

	Cat #12	Other Tandems Maximum	Other Tandems Minimum
Overall weight	24,690	27,950	25,100
Wt. on drivewheels	17,200	19,300	17,600
HP	100	100	113
LBS/HP (Total wt.)	247	280	222
LBS/HP (Drivewheel wt.)	172	193	156

The Cat #12 falls into the intermediate class in this ratio comparison. What to consider as the ideal relationship between horsepower and weight is not known. It was noted that two machines were excessive drifters. Computation showed the ratio of overall weight to horsepower of one to be 236 and the other 222. The ratio of drivewheel weight to horsepower was 165 and 156 respectively. The Cat #12, with ratios of 247 and 172, was judged to be stable, with good work performance. The grader with the largest ratio was definitely the most stable of all units tested.

It is not the intent of this report to determine the ideal ratio, but merely to suggest that this weight power relationship may play an important part in performance of a grader.

DIMENSIONS

Of all the machines tested, the Cat #12 was intermediate in overall length, width and wheelbase. Vertical clearance inside cab was 69"; the least of any grader tested. However, a 6" deep "well" was provided as an accessory item to increase this dimension to 75" which was within $\frac{1}{2}$" of the maximum recorded for any unit. The adequacy of the inside cab dimension of 69" (without well) is questionable. Overall height of the Cat #12, with and without cab, was within the average limits of all graders tested.

Frame section of the Cat #12 was comparable in size and weight to the frames of other graders tested, and appeared adequate.

SPEEDS

The Cat #12 had six speeds forward and two reverse. Gear reduction was such as to provide adequate speed and power for all types of work included in the test. The comment here applies only to speed variations and is not intended to cover the transmission as a mechanism for changing speeds, or control of the grader at various operating speeds. This is discussed elsewhere in the report.

ENGINE

The unit had a Caterpillar engine, six cylinder, four stroke cycle diesel, with a bore of $4\frac{1}{2}$" and stroke of $5\frac{1}{2}$", displacement of 525 cu.in., and was rated at 100 brake horsepower maximum at a governed speed of 1800 rph. The engine had a crankcase capacity of 23 qts., and the recommended fuel was commercial diesel. The auxiliary starting engine was two cylinder, four cycle, used gasoline fuel, and was equipped with 6-volt electric starting motor. Starting of main engine was by the auxiliary starting engine.

I. BLADE OPERATION

A. Operation of Circle. The time required for one cycle of operation of the blade circle on the Cat #12 was 52 seconds, which was the slowest of the graders, with mechanically operated controls. The minimum for this particular group was 40 seconds. Two of the graders had hydraulically operated controls and time for these was recorded at 2 minutes, 19 seconds; and 1 minute, 50 seconds. With scarifier teeth removed, the 12-foot blade could be revolved in a 360° cycle without difficulty.

B. Locking Devices. The Cat #12 did not have a separate locking device to prevent shifting of the blade under load, but depended upon worm and worm gears with friction drags on worm drive to lock controls in position. This system was similar to that used on other graders tested which had mechanically operated controls. Only one machine tested had mechanically operated controls. Only one machine tested had a separate positive cab controlled circle lock.

C. Bank Sloping Positions. The Cat #12, like all other machines tested, had no special attachments for bank sloping. It was able, without difficulty, to reach all normal bank slope positions by shortening and lengthening linkage.

The following tabulation, Table III, shows the height of the blade tip and the position of the heel of the blade for various bank slope positions, together with maximum and minimum measurements for other machines tested.

TABLE III

Bank Slope Blade Positions

Bank Slope	Angle	Measurements (In inches)	Cat.	Other Machines Tested Maximum	Other Machines Tested Minimum
1½:1	34°	Height of tip above ground	36"	65"	32"
		" " heel " "	0	0	0
		Distance heel inside ref line	0	24	0
		" " outside " "	0	0	0
1:1	45°	Height of tip above ground	63"	81	49
		" " heel " "	0	0	0
		Distance heel inside ref line	0	10½	0
		" " outside " "	0	0	0
3/4:1	53°	Height of tip above ground	91"	112	82½
		" " heel " "	0	0	0
		Distance heel inside ref line	0	6½	0
		" " outside ref "	0	6	0
½:1	63°	Height of tip above ground	106"	123	84
		" " heel " "	0	0	0
		Distance heel inside ref line	0	0	0
		" " outside " "	14½	15½	0
¼:1	76°	Height of tip above ground	*No test	138½	76½
		" " heel " "		6½	0
		Distance heel inside ref line		0	0
		" " outside " "		23-3/4	12

A re-run of test of Bank Slope Blade positions was made with all machines, to obtain more accurate date. In the meantime, a bulldozer attachment had been installed on the Cat #12 and it was decided to attempt to attain test slop angles with this attachment intact. A maximum of only 63° was attainable. Interference between the circle drawbar, scarifier linkage, and bulldozer attaching frame prevented the attainment of over 63°. Previous bank slope tests of the Cat #12, without bulldozer attachment, proved the 76° angle could be attained without difficulty. Refer to photographs, Figures 7 and 8.

Figure 7. Bank Slope Angle - $\frac{1}{4}$:1

Figure 8. Interference of Dozer Support Frame at 63° Bank Slope.

D. <u>Side Shift</u>. From center normal operating position, the blade was shifted 25" to the right at ground level by means of the lift and lateral controls. This was with the lateral linkage set for right hand operating position. With the lateral link set for left hand operating position, the blade was shifted an equal distance to the left. This compared with a minimum of 16½" and a maximum of 25¼" for the other machines tested. The time for the shift from center position to maximum right and return to center was 66 seconds, as compared with the minimum of 42 seconds and maximum of 65 seconds for the other machines. Due to the different distances of shift, these time figures were reduced to shift in inches per second, and are shown in the following Table IV.

TABLE IV

Blade Side Shift

With Blade Centered on Circle	Cat #12	Other Machines Tested	
		Maximum	Minimum
Distance right	25"	25¼"	16½"
Shift in./per sec.	.76	.98	.61

On the machines tested, there were three methods of blade side shift on moldboard arms: (1) power ram, (2) unbolting and rebolting blade, and (3) blade slide. Time for blade shifting on machines where blade was unbolted, shifted and rebolted, averaged 9 minutes, 9 seconds. Machines using slide mechanism averaged more than 20 minutes.

The time required to offset the Cat #12 blade on the circle was not obtained with accuracy. Difficulty was encountered in the first attempt due to a binding condition. This was conceded to be caused by heavy paint on the blade shift sliding surfaces, as shifting was accomplished more freely after paint was removed. However, due to the tendency to bind, and uncertainty of positive lock position, this particular method as used on the Cat #12 was considered by test observers to be less desirable than the power ram or unbolt-rebolt methods used on other units. Photograph, Figure 9, shows blade side shifted on circle.

Figure 9. Blade Side Shift

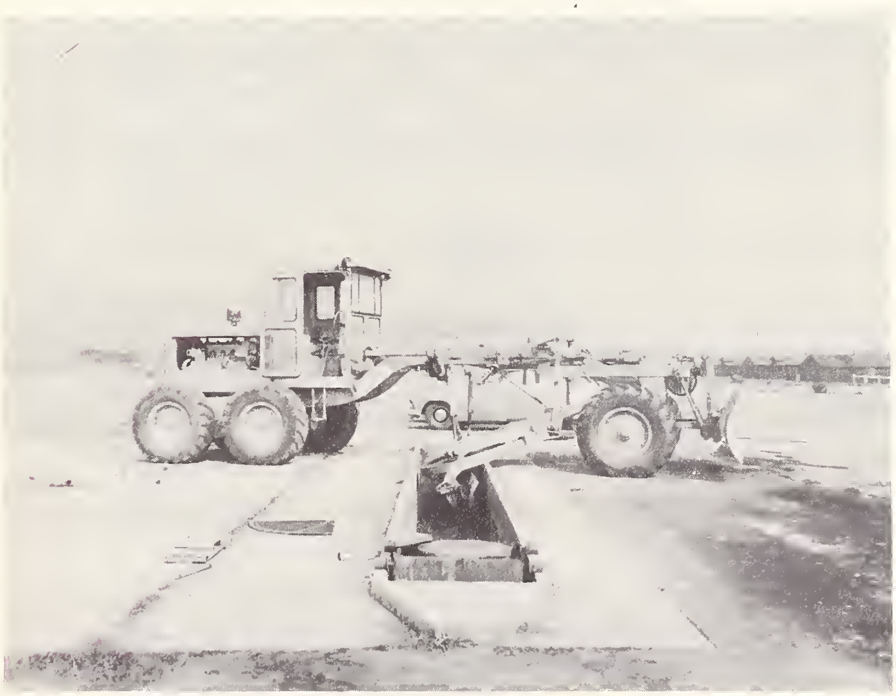


Figure 10. Maximum Drop Below Ground

E. Blade Lift. The maximum lift of blade above ground, drop below ground, angle of lift right and left with blade centered, and the clearance between blade cutting edge and bottom of circle are given in the comparison Table V.

TABLE V

Blade Lift

With Blade in Normal Operating Position	Cat #12	Other Machines Tested Maximum	Minimum
Max. lift above grd.	$15\frac{1}{4}$"	16"	14-3/4"
Time for max. lift	7 sec.	15 sec.	6-3/4 sec.
Rate of lift (in. per sec.)	2.18	2.37	.98
Max. Drop below grd.	$10\frac{1}{2}$"	$23\frac{1}{2}$"	5"
Clearance blade cutting edge to circle	25"	$28\frac{1}{2}$"	$24\frac{1}{2}$"
Max. angle right	8°	$15\frac{1}{2}^{\circ}$	$8\frac{1}{2}^{\circ}$
Max. angle left	8°	$13\frac{1}{2}^{\circ}$	$8\frac{1}{2}^{\circ}$

In the above group of operations, the Cat #12 was average compared to the other machines, with the exception of maximum right and left angles. In this respect, the 8° angles were the minimum for any machines tested. Photograph, Figure 10, shows maximum drop of blade below ground.

F. Blade Reverse. This operation was accomplished by the Cat #12 without difficulty.

G. Blade Pitch Positions. The table of pitch positions and angle of pitch is given in Table VI.

TABLE VI

Blade Pitch

	Cat #12	Other Machines Tested Maximum	Minimum
PITCH Forward	+ 39°	+ $43\frac{1}{2}^{\circ}$	+ $27\frac{1}{2}^{\circ}$
PITCH Rear	+ 1°	- 17°	+ 9°
PITCH Positions	13	15	6

The angle of pitch and number of pitch positions of the moldboard on the Cat #12 compared favorably with that of the other graders tested.

H. Visibility. Visibility of wheels and blade is of special importance in mountain operations where steep grades, narrow roads, and short radius curves are prevalent. None of the units tested had complete visibility, since all had mechanisms that partially obstructed the operator's view of either blade or wheels. It was the consensus of observers that the Cat #12 rated number one (fabcrably) of the five machines tested. Refer to photograph, Figure 11, a sitting view from the cab.

II. WHEEL LEAN

Test date for the unit is shown in Table VII, with maximum and minimum of other graders tested.

TABLE VII

Wheel Lean

	Left	Right
Cat #12	20°	20°
Maximum Other	21½°	22½°
Minimum Other	15½°	11°

The wheel lean, both right and left, on the Cat #12 was second highest of any of the graders tested.

There were no published data to indicate what the designated wheel lean should be. From analysis of grader performance during the tests, it appeared that 20° wheel lean was approximately the minimum that would give adequate control to tandem machines.

III. GROUND CLEARANCE

Ground clearances for the Cat #12 are listed in Table VIII, with maximum and minimum values for the other tandem graders tested.

TABLE VIII

Ground Clearance

		Other Tandems Tested	
Item	Cat. #12	Maximum	Minimum
Wheels vert. behind blade	13½"	13"	10-3/8"
Front of blade	22"	27½"	19-3/8"

The Cat #12 had the most clearance behind the blade of any of the tandems tested, and was rated third of four for ahead of blade clearance. No operational difficulties could be attributed to lack of ground clearance.

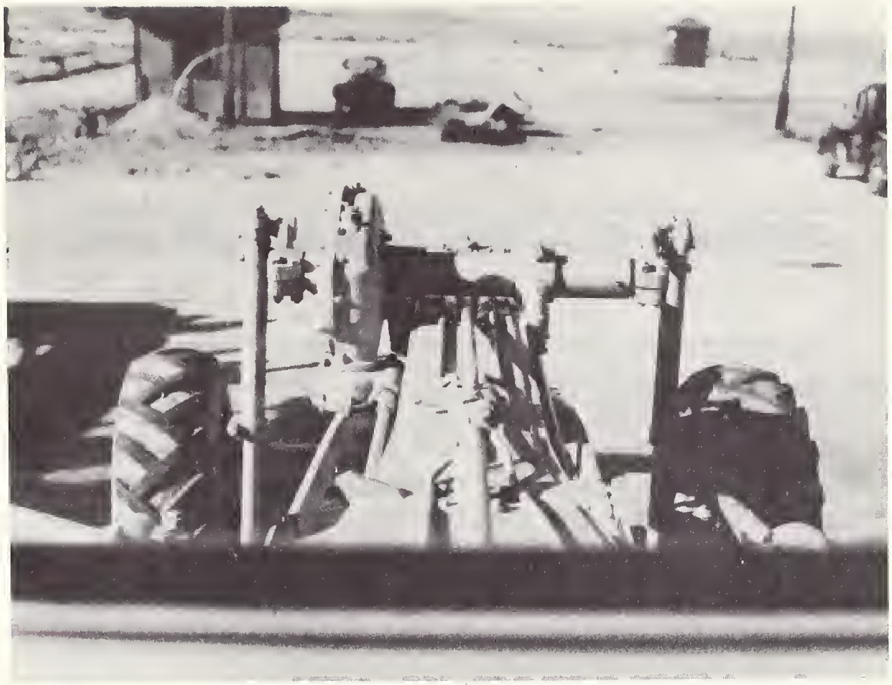


Figure 11. View from Cab

Figure 12. Wheel Lean - Cat. Mod. #12

IV. FRONT AXLE TREAD

Test data are shown in Table IX.

TABLE IX

Front Axle Tread

Cat. #12	Maximum Other	Minimum Other
79½"	83¼"	79"

The Cat #12 front axle tread was within 1/2" of the minimum of any unit tested.

There were no operational difficulties noted during the tests which might be attributed directly to excessive tread width.

V. SERVICING REQUIREMENTS

Records were kept of the fuel used by all of the machines tested. The table below shows fuel consumption and hours operated for the test period.

TABLE X

Fuel Consumption

	Cat. #12	Maximum Other	Minimum Other
Fuel - gal.	266	272	209
Hours	86½	113	58
Gal/Hr	3.07	3.76	2.41

The total number of service points and the number requiring daily, weekly and monthly checks are shown in Table XI.

TABLE XI

Service Data

	Cat #12	Grader A	Grader B	Grader C	Grader D
Total serv. points	112	101	103	114	70
No. daily services	4	92	46	63	40
No. weekly "	77 (20 hrs.)	6	34	50	9
Other	31	3	23	1	21
Total points to service during wk.	174	466	264	365	209

The data in the above table are not exactly in accord with the manufacturer's recommendations. This is primarily because of the difficulty in determining the actual lube points from the instructions furnished, and also because of the use of other than daily and weekly periods. It does, however, represent the observer's best estimate of service requirements.

While the conclusions that could be drawn from the table may be considered insignificant, the problem of lubricating machines is important. Each point requiring lubrication is a potential source of trouble if not serviced. Time for servicing, particularly daily service, is most often lost time from production.

The Cat #12 showed the total number of points serviced weekly to be the lowest for the group. Apparently, the Caterpillar Tractor Company has made an effort to keep service labor to a minimum.

VI. TIRES AND RIMS

Tires on the Cat #12 were Firestone 13:00x24 - 12 ply, and rated with the heaviest in the 13.00 size. Inspection upon completion of the test showed wear on tires to be negligible and only one small sidewall cut on right rear tandem was found.

Figure 13. R.R. Tandem Side Wall Cut

Notes taken from the field data are listed below for comparison.

Cat #12: Wear - "Negligible", Breaks - "None" (one small cut, sidewall, R.R. tandem.)

Grader A: "Tires badly worn and cut."

Grader B: Wear - "Negligible", Breaks - "None".

Grader C: Wear - "Negligible", Breaks - "No breaks."

Grader D: Wear - "Very little wear", Breaks - None some rock cut - not serious."

Drop center taper bead rims with lock rings were used on the Cat #12. No rim difficulty was experienced.

VII. TANK CAPACITY

Comparative tank capacities are shown in Table XII.

TABLE XII

FUEL TANK CAPACITIES

Cat #12	Max. Other	Min. Other
60 gal.	58 gal.	45 gal.

Tank capacity of the Cat #12 was adequate for more than eight hours of field operation.

VIII. REMOVAL OF WINDOWS, DOORS, AND CAB

The actual time required to remove the Cat. #12 cab was not determined. It was estimated that doors, windshield, and rear cab glass could be removed in about 15 minutes.

The problem in connection with cab, door, and window removal was almost the same for all graders, with the possible exception of one. This unit had hinge-pins for removing windshield, rear cab glass and doors, which facilitated their removal.

All cabs could best be handled with shop facilities, and would require approximately the same time to effect removal.

IX. LIGHTS

Intensity of lights, measured with a Weston meter three feet from the light source, varied from slightly under 800 to 1200 for the five graders tested. The value for the Cat #12 was 1200. From the testing of lights on all graders, it was concluded that all were adequate for travel illumination, but possibly would not comply with State Highway Codes in all instances.

There appeared to be no standard for mounting the lights. Locations varied from top of cab to bottom of cab, and on one unit were mounted on the lift supports. Some lights were adjustable, some were not. Some were protected, others were not. Some illuminated the blade, those on the Cat #12 did not. In no case were the differences because of lights or mountings considered important.

Data recorded for the lights as furnished with the Cat #12 are tabulated below:

Location	- Near top of cab
Number	- Two
Weston intensity	- 1200
Protected	- Yes
Adjustable	- No
Illuminated blade	- Not as mounted
Adequate for night travel	- Yes

The observers agreed that in future consideration of lights for motor graders, more emphasis should be placed on adjustable mountings which would permit night illumination of the blade, protection for lens on forward lights, and some provision for backup lighting.

X. ENGINE STARTING

The average time and temperature for four cold starts is shown in Table XIII.

TABLE XIII

Engine Starts

	Cat #12	Max. Other	Min. Other
Average time	133 sec.	129 sec.	10 sec.
Average Temp.	42°	59°	46°

No difficulty was experienced in starting the Cat #12 engine at any time during the test. However, average starting time for this machine exceeded the maximum average for all others tested. In this respect, the starting system employed by the Cat #12 was conceded to be the least desirable of the starting systems. The need for an auxiliary engine to accomplish this function appeared superfluous when compared to the more simple and self-contained means of starting employed by each of the other graders, whether by gas-to-diesel conversion, or straight diesel cycle starting. Even though the starting engine on the Cat #12 is electric starter equipped, the sequence of starting a gas engine, warming it up, employing separate clutch and transmission to adequately prepare the main engine for diesel cycle starting appears entirely disadvantageous when compared to the more simple methods demonstrated. This viewpoint covers starting principle only, and disregards the factor of maintenance involved in the auxiliary engine and related mechanism necessary to accomplish main diesel engine starting.

Some grader engines employed the use of ether pills to assist in adverse cold conditions. Field reaction to the use of ether pills was adverse at the beginning of the test, but was conceded to be a practical method toward the end. Actually, the procedure is simple. In the opinion of the observers, the two engines equipped with ether assists were rated the highest in their ability to make fast starts.

XI. OPERATION OF CONTROLS

The discussion here is confined only to the actual controls as mounted in the cab.

Some difficulty was experienced with the functioning of the hand levers which control the grader mechanism on the Cat #12. In certain conditions when a control movement was made under considerable pressure, the control lever involved would forcibly "kick back" in the operator's hand. This "kick" action was attributed to a dog type clutch engaging mechanism, which had a tendency to disengage when power control was applied. Two other graders with mechanical control mechanism were tested, but the "kick" of the hand control levers, altho present, was not severe to the extent of that on the Cat #12. This item is brought to attention as a matter contributing to operator fatigue rather than control inadequacy. In this respect, it was the consensus of observers and Forest Service operators that hydraulic controls did not involve a similar fatigue problem.

The Cat #12 grader was equipped with a throttle decelerating device similar to a conventional foot throttle. Its purpose was to decelerate the engine to any speed desired below the hand throttle setting. Release of the foot pedal automatically returned the engine speed to the preselected hand throttle setting.

This device was of particular advantage when the operator had his hands too occupied with controls to use the hand throttle. Variable engine speed was easily accomplished.

Operators and observers agreed the decelerating device to be a desirable feature for all motor graders, altho none of the others tested were similarly equipped.

Cab controls on the Cat #12 were considered adequate and satisfactory, with the exceptions covered.

XII. TURNING RADIUS

(1) - After the first trials, it was established that turning radius alone is meaningless unless road width required for the turn is known. Accordingly, turning radius was established as the radius of the inside track of a complete turn. The distance between inside and outside tracks was taken as the required road width for the turn.

TABLE XIV

Turning Radius

	Cat #12	Max. Other	Min. Other
Turning radius - right	21'-10"	27'-9"	22'-1/2"
Turning radius - left	28'- 1"	29'-3"	22'-9"
Average road width	13'-5½"	13'-4½"	8'-1"

It will be noted that the turning radius for the Cat #12 was within the maximum-minimum recorded for any other grader tested. However, there was considerable variation of right and left radius dimension. As this variation was apparent on the first test trial, the Cat #12 representative was permitted to make correction, which was done by repositioning the drag link steering arm on its shaft. The test was re-run and the results as tabulated above indicated correction had not been satisfactorily accomplished.

Average road width required for turn of the Cat #12 showed it to be the maximum required for any unit tested.

The test showed conclusively that none of the tandem graders tested could make a minimum radius turn on a 12-foot road bed.

(2) - Turn-Around. The results of the turn-around test are shown in Table XV.

TABLE XV

Turn-Around

Backups Required on	Cat #12	Max. Other	Min. Other
35-Foot Road	2	4	2
30-Foot Road	5	8	3

The Cat #12 was well within the maximum-minimum backups required by the graders tested to accomplish the turn-around test.

It was during this test that the need for a steering booster or similar means became particularly apparent on heavy type motor graders equipped with large front tires and worm and sector type mechanical steer. For some undetermined reason, the booster failed to function on the Cat #12, and steering reverted to a strictly manual function. In the above test, (which simulated an actual restricted turn-around space) front wheels had to be turned from one extreme to the other without machine movement. It was only with effort that the operator could effect turning of the front wheels under these conditions, and considerable time was required to do so. This point is brought to attention to emphasize the need for a means of steering control which will function safely and with minimum effort under all operating conditions.

XIII. BRAKE TEST

The service brakes on the Cat #12 were straight hydraulic type, mounted on rear tandem wheels only.

The following table gives a comparison of the holding and stopping ability of service and parking brakes of the Cat #12 as compared with the maximum and minimum values found for other machines tested.

TABLE XVI

Brake Tests

		Other Machines Tested	
	Cat #12	Maximum	Minimum
Serv. brakes uphill hold	49%	49%	21%
Serv. brakes downhill "	49%	49%	34%
Park. brakes uphill "	49%	49%	21½%
Park. brakes downhill "	49%	49%	15%
Stopping distance at 18 mph.	32 ft.	38 ft.	15 ft.

California State Vehicle Code stopping distance at 18 mph - 30 feet.

The above table indicates that for stopping ability on steep grades at slow speeds, the service brakes of the Cat #12 were adequate. For quick stopping at high speeds, the service brakes were classed as fair. Although the California State Vehicle Code for braking distances does not apply to motor patrol graders, the stopping distance requirements were used as a check on the ability of motor graders. One tandem machine had brakes capable of stopping in 19 feet at 18 mph. and was considered entirely adequate. The unit with stopping distance of 38 feet was considered inadequate.

XIV. WALKING TEST

1. The highway walking test was divided into two sections. The first covered travel over asphalt paved highway with with grades up to two percent. The second covered travel over dirt highway with grades up to eight percent.

2. The truck trail walking test was divided into uphill and downhill sections. Grades varied from 14 percent uphill to 10 percent downhill.

Table XVII gives comparative speed data in miles per hour for each section of the highway and truck trail runs as well as overall mph for each distance.

TABLE XVII

Travel Speed (MPH)

Route	Distance	Cat #12	Other Graders Tested Maximum	Other Graders Tested Minimum
Paved highway	4.2 Mi.	19.90	24.60	15.80
Dirt highway	1.9 "	17.54	16.38	12.35
Total highway	6.1 "	19.10	19.94	14.50
Uphill T.T.	1.35 "	6.56	6.37	4.49
Downhill T.T.	2.3 "	14.33	16.24	9.13
Total T.T.	3.65 "	9.98	8.52	7.70

In the highway test, the Cat #12 was above the average of the other machines tested, and was fastest of the group in the truck trail walking test. No difficulties with the Cat #12 were observed in these tests.

XV. BREAKDOWNS

In terms of the definition of breakdowns, as it applies to lost operating time, the Cat #12 did not at any time fail during the tests.

The only incidents which might be considered under this term "breakdown" were as follows:

1. Breakage of one cutting edge. Altho a section of several inches was broken from a cutting edge, and a scarifier tooth broken, they were considered normal job hazards and not machine failure.

2. Failure of steering booster to function. As noted under Table XV, Turn-Around, the steering power booster failed to function, this caused very difficult steering. However, this failure only detracted from the ease of steering, necessitating increased manual effort. A safety hazard or loss of time was not involved.

XVI. FINAL CHECK

On completion of the field tests, all machines were returned to the "flat land" area. All complaints recorded were given a final check. In addition, a thorough check of each grader was made by shop mechanics. Items of apparent or actual fault, minor or otherwise, were recorded for the Cat #12 as follows:

1. Slight oil drip at companion joint between transmission and differential housing.

2. Slight oil drip at both tandem oscillating axles.

3. Indication of excessive oil leak at main engine front bearing, altho no leakage was evident at time of final inspection. This leakage was very evident during slide removal. Examination as to cause revealed that the engine crankcase had inadvertantly been overfilled in servicing. Refer to photograph, Figure 14.

4. Mounting bolts of circle and lateral shift housing were loose.

5. Wheel axle flange bolts (to tandem housing) loose and leaking oil.

6. Bearing on leaning wheel gear housing leaking oil.

7. One of the brackets for adjusting blade pitch was bent. Refer to photograph, Figure 15.

8. Front Wheels, when checked, showed $2\frac{1}{2}$" tow out.

9. Several items pertinent to the bulldozer were also recorded, and are covered under that subject later on in this report.

Figure 14. Front Bearing Oil Leak

Figure 15. Blade Pitch Bracket - Bent

DISCUSSION OF RESULTS

Field Tests

I. SLIDE REMOVAL

One fact brought out by this test was the lack of knowledge of various operators as to how much work a machine was capable of doing. In the case of the slide removal, the operator's normal reaction was that the grader would be unable to do the task. As the test progressed, the performance of machines improved as the operators gained more experience. Table XVIII gives comparative times required for machines to climb over the test slide.

TABLE XVIII

Slide Removal

Time to	Cat #12	Other Machines Tested Maximum	Other Machines Tested Minimum
Climb slide	21 min.59 sec	50 min.	15 min.57 sec.

The time required to climb the slide was reflected in a combination of operator and grader ability, plus the method used. For example, the original time for the Cat #12 was reduced three-fourths in a rerun test. The reduced time factor was attributed to two causes: first, the operator gained experience by his original trial of a grader function with which he wasn't familiar. Second, in the interim, he had the opportunity to observe time saving advantages evidenced by other graders and operators performing the same test, thus enabling him to beneficially apply the experience and knowledge gained.

The true value of the slide test was not in determining the time required, method of attack, number of passes, etc., but in the appraisal of grader maneuverability, traction, blade stability, and operator fatigue.

The Cat #12 rated second best in elapsed time. The machine with minimum time was able to accomplish the job by swinging the blade circle while heavily loaded. The machine requiring the longest time was the first of the graders to attempt the slide test. It was made without benefit of previous experience or precedent, and no rerun was made by this machine.

Climbing ability of the Cat #12 and all other factors considered important in this test were adequate.

Figures 16 and 17 show the slide before and while being worked on by the Cat #12.

Figure 16. Slide - Before Test

Figure 17. Slide - During Test

II. IN-CURVE

In Figure 5 is depicted a typical condition often encountered in forest road maintenance. To operate on roads on which such conditions occur, a grader which is capable of turning a short radius curve, using the minimum of road width, would be the most desirable. Operation under these conditions proved to be difficult for all tandem graders. The road widths required by the Cat #12 was 19' - 7½". This compared favorably to the average of 19' - 9½" for all of the other tandem machines tested. The four-wheel steer machine which required a road width of only 9'-7½" had the decided advantage. Data obtained from this test substantiated the conclusions of the "flat lands" turning radius runs.

III. GRADING OF DIPS

No difficulty was encountered with the Cat #12 in grading dips. Maneuverability of machine and operation of controls was adequate in all respects.

IV. DITCHING

The site of this operation was in the same area worked on by other units and test strips were adjacent in order to obtain conditions as comparable as possible. The Cat #12 accomplished this test in the least time. The table of ditching time, Table XIX, shows the comparison between the Cat #12 and other machines in the test.

TABLE XIX

Ditching

		Other Machines Tested	
	Cat #12	Maximum	Minimum
Time to Construct Ditch	8 H.20 M.	11 H.33 M.	8 H.58 M.

It was recognized that this ditching test was most severe and beyond the normal operations encountered or anticipated. Refer to photograph, Figure 18. It was, in effect, an accelerated aging test to determine the ability of the graders. It was the expressed opinion of observers that the Cat #12 and one of the other graders were driven harder by the operators in this test than any of the other units. This undoubtedly contributed to the record of minimum time. In spite of this, however, no detrimental effects to the machine were noted. This was considered by observers to be complimentary to the design and structural adequacy of the Cat #12. Refer to Figure 19 for the finished ditch.

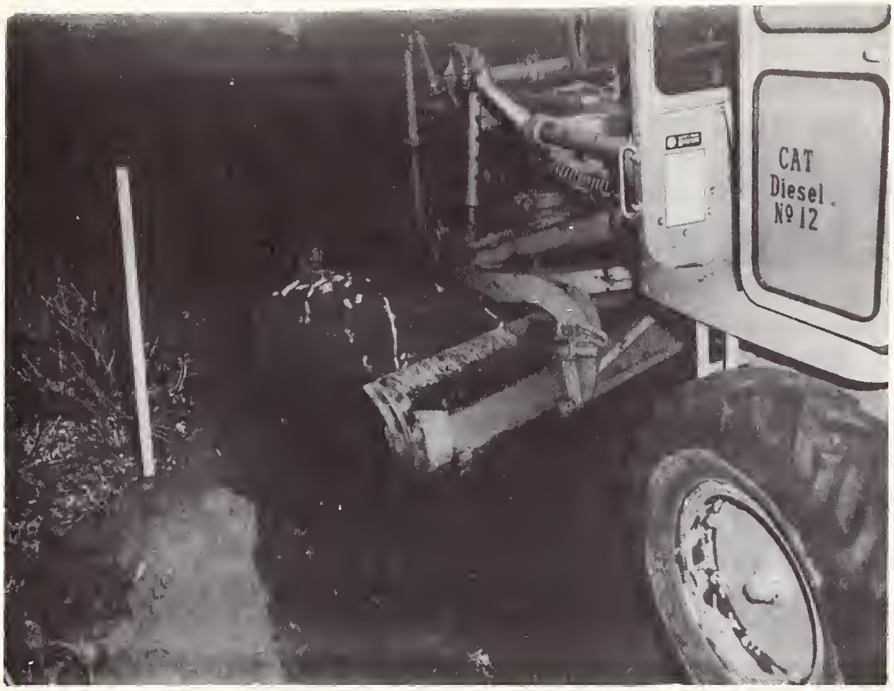


Figure 18. Rock Removal in ditching Operation

Figure 19. Finished ditch.

V. SCARIFYING

The work of scarifying the ditch surface was accomplished equally well by all graders. One tooth was broken on the Cat #12, either because of the size of the embedded rocks or possible operator abuse. This was classed by observers as a normally expected job hazard.

VI. BANK SLOPING

The Cat #12 accomplished the bank sloping test comparable to other acceptable tandems. Maneuverability and control of both machine and blade were judged adequate by test observers. However the Cat #12 had some difficulty in bank sloping on short radius inside curves. The long wheel base made it impossible to get close to the bank, even though blade was at maximum reach.

To compensate for the above situation, one front wheel was usually driven on the bank. It was noted that when front wheel was driven on the bank, any irregularity of contour was often directly reflected in a similar irregularity in the bank slope cut.

It was conceded by test observers that all tandem graders would have some difficulty in bank sloping short radius inside curves. On outside curves and tangents this difficulty was not apparent. Refer to photograph, Figures 20 and 21.

Figure 20. Bank Sloping

Figure 21. Bank Sloping - Outside curve.

VII. DRIFTING

The comparison Table XX for the drifting operation shows that the Cat #12 out rated all other machines in this test by moving .17 cu. yds. per minute more than any other grader. This apparent superiority could not be traced to any design feature.

TABLE XX

Drifting

	Cat #12	Other Machines Tested Maximum	Other Machines Tested Minimum
Cu. yds./Min. Moved	1.29	1.12	0.97

VIII. HORIZONTAL MOVEMENT OF WINDROW

In this test, results were expressed in cu. yds. feet side cast per minute. This factor is necessary for comparative purposes, since each machine moved a different quantity of dirt variable distances to the side, and in variable periods of time. Table XXI gives the results.

TABLE XXI

Windrow-Cu. Yds.-Ft./Min

Cat #12	Grader A	Grader B	Grader C	Grader D
107.0	149.0	85.5	145.2	96.5

In production, the Cat #12 rated third. No difficulty was encountered during this test and the finished result was acceptable.

IX. SHAPING OF BERMS

The work in this test was relatively light and all units were rated equally. No significant features or failures of the Cat #12 were evident.

X. HILL CLIMB

In this test all machines climbed the 49% grade in forward gear. In reverse, the tandem machines were able to back up to the section of the hill on which the slope varied from 39% to 41%. At this point failure was due to lack of traction. The four-wheel-drive unit was the only one able to climb the hill in reverse.

XI. UPHILL GRADING

Road sections selected for this test averaged about 15% grades and road bed material was chiefly decomposed granite. Table XXII Gives the comparative overall time required by the graders to complete a 500 ft. grading job.

TABLE XXII

Uphill Grading

Time to do	Cat #12	Other Machines Tested Maximum	Other Machines Tested Minimum
Uphill Grading (500 Ft.)	2 Min. 50 Sec.	4 Min 6 Sec.	3 Min. 23 Sec.

The Cat #12 completed this test in the minimum of time with satisfactory results.

XII. ROAD GRADING

The three-pass 500 foot road maintenance test was preliminary to the two mile maintenance run. Performance assured observers of the ability of machine and operator to proceed with the longer test to follow.

XIII. ROAD MAINTENANCE

The two mile road maintenance run was the last of the field tests performed, and combined all of the operations, normally required in road grading with the exception of bank sloping. This being the composite of the previous tests, the observers were able to recheck various phases of operation previously noted, as well as to appraise the ability of the machine in shifting from one operation to another with minimum loss of productive time.

The course selected for the Cat #12 test was 1.9 miles long, had 65 interceptor dips, 13 minimum radius curves (less that 35') and had grades up to 20 percent. The roadbed consisted of decomposed granite, loam and some rock. Three passes were made averaging 1.9 miles per hour, or a total time of 3 hours for the test. Speed of other graders ranged from 1.47 to 1.76 miles per hour, or an average of about .28 mph less than the Cat. #12. A considerable portion of the variation in time could be directly attributed to difference in operator interpretation of the problem.

Finished results of the Cat #12 road maintenance tests were scrutinized carefully by a Forest Service engineer. Altho completed in a comparatively minimum time, it was his opinion that the quality of road màintenance was inferior to recognized standards. Unfinished appearance, and improper cutting and placement of material were evident.

As for the unfinished appearance it was the opinion of observers that the operator gave more attention to a reduced time factor than work quality. This cancels any reflection that the Cat #12 was incapable of performing to normal standards.

Many photographs were taken of the test in an effort to record the operation. These were studied during preparation of the report. Four which were considered pertinent are shown as Figures 22 to 25.

Figure 22. Typical Section Prior to Grading.

Figure 23. Same Section after Road Grading.

Figure 24. Completed Section of Road Grading

Figure 25. Completed Section of Road Grading.

BULLDOZING TEST - FLATLAND AND FIELD

Due to the specialized nature of bulldozer attachments on graders, this portion of the test was treated independently of the basic grader test. Considerable interest in the possibilities of such an attachment was indicated by observers, and as a result, the Caterpillar Tractor Company and one other grader company voluntarily sent for and installed their respective dozer attachments for testing.

Comparative data for both dozer units as taken in the Flatland test were as follows:

	Cat #12	Other Unit
Weight, blade assembly	880 lbs.	1500 lbs.
" attach. "	1480 "	----
" total "	2360 "	*1500 "
Blade length	10'-0"	9'-0"
" height	2'-7"	3'-3½"
Pitch	1°-8° +	Fixed
No. cutting edges	2	1
Cutting edge size	6"W x 5'L	8"W x 9'L
Max. angle R	33°	0° (Fixed)
" " L	33°	0°
Type control	Mech.	Hyd.
Max. lift above ground	17"	17"
Max. lower below ground	6"	6"
Side shift range	8" R and L	0"

* Add 300 lbs. for attaching parts of grader not equipped with scarifier controls.

The combined time (operator and 1 helper) required to install the respective units was recorded as follows:

Cat #12	6 hours total
Other Unit	44 minutes total

The Cat #12 dozer and attaching assembly is comprised of extensive frame work, shafts, gear box, linkage, shaft pins, etc. which was the cause of the longer installation time. The other dozer unit was installed by simple attachment at three points. However, once installed blades only could be removed or replaced in comparable time. Photographs Figures 26 and 27 show Cat Dozer Blade installation.

Figure 26. Caterpillar Dozer Attachment.

Figure 27. Dozer in Operation.

When the bulldozer was installed the operator's forward visibility was decreased by blade and blade operating mechanism.

Bank slope positions in excess of 63° could not be obtained due to interference between bulldozer support frame, and circle and left arms.

In the slide removal operation the Cat #12 was able to surmount the slide in 19 minutes and 10 seconds. This time was 2 minutes and 49 seconds less than was required by the grader when not equipped with dozer. The dozer blade was angled and a rerun of the slide was made. In this operation the time required was 15 minutes 29 seconds or 3 minutes 41 seconds less time than was required with the straight blade. Operation was hampered due to the fact that the blade could not be lowered sufficiently to pick up a full load of dirt.

CONCLUSIONS

Conclusions formulated and expressed are the result of experience with and test of the machine submitted for trial.

FLATLAND TESTS

1. Weight distribution for the Cat #12 conformed to standard tandem practice.

2. Weight horsepower ratio was considered to be in proper balance.

3. Overall dimensions were comparable to those of all other acceptable tandem graders.

4. Speed variations, as allowed by rear axle and transmission ratios, were adequate.

5. Engine performance was satisfactory.

6. Method and principle of starting, while adequate, was considered the least desirable of any unit tested.

7. Blade maneuverability in all tested operating positions was satisfactory.

8. The manual blade side shift as used on the Cat #12, was considered the least desirable method.

9. Visibility from the cab was rated superior.

10. Wheel lean was considered adequate.

11. Ground clearance was better than average and adequate.

12. Daily maintenance requirements were comparatively at a minimum.

13. Tires as furnished were adequate.

14. Rims, as furnished, were satisfactory.

15. Fuel tank capacity was sufficient for a full day's operation.

16. Cab removal and reinstallation problem was comparable to that of other graders.

17. Lights were satisfactory for forward illumination only.

CONCLUSIONS (Cont.)

FLATLAND TESTS (Cont.)

18. Controls were adequate and satisfactory with exception of "kick" action of control levers under certain operating conditions.

19. Operation of control levers on the Cat #12 was more fatiguing to the operator than the hydraulic type.

20. Hand throttle control was adequate.

21. The throttle decelerating device was considered desirable feature.

22. Turning radius, altho comparable to other tandem graders, required maximum roadwidth to make the turn.

23. Service and parking brakes were adequate.

24. Travel speeds were adequate.

FIELD TESTS

1. The Cat #12 made a creditable showing in climbing over the slide.

2. Results of in-curve test showed maneuverability comparable to other tandems. Performance, however, was handicapped by road width requirements for short radius turns.

3. Performance of the Cat #12 in constructing and maintaining dips was adequate in all respects.

4. In the ditching operation the Cat #12 did the best job in the shortest time without difficulty other than operator fatigue.

5. The scarifying test was accomplished satisfactorily.

6. Bank sloping ability of the Cat #12 was above average.

7. The Cat #12 outperformed all other graders in the drifting test.

8. In the windrow test the Cat #12 rated third indicating an acceptable performance for normal field operations.

9. Berm shaping was accomplished satisfactorily.

FIELD TESTS (Cont'd)

10. In the hill climb test the performance of the Cat #12 was equal to that of all other tandems tested.

11. The Cat #12 showed superiority over other test machines in completing uphill grading on steep slopes in the minimum time.

12. The overall job on the two mile maintenance section was rated as poor.

13. After reviewing all operations under test conditions it was the consensus of observers that the Cat #12 was one of the better tandem graders tested and capable of satisfactory performance to Forest Service Standards.

A P P E N D I X

RATING TABLE

As a check on the results of the motor grader test, a rating table was prepared to include several of the more common items generally considered when discussing patrol graders. The theory in the preparation of this table, if it can be so called, is based somewhat on the laws of random sampling.

Eight men - three engineers, one ranger, one mechanical draftsman-designer, two Depot Superintendents, and one Regional Office staff man - completed a rating table for the five graders, to include twenty-three items normally associated with equipment of this type. The items were listed only as headings with no detail to cover definition. Instructions for preparation requested that the rater draw his own conclusions as to the inference in the item, and rate accordingly. Rating was to be made by indicating the best as one, second best - two, etc., with machines of equal ability being rated by the same digit.

It was also recognized that all 23 of the rating items did not bear the same weights as to importance. Accordingly, each person preparing the questionnaire was requested to evaluate the relative importance of each and establish some weighting scale to cover.

A typical final form is shown with the items weighted, but without the ratings for the individual graders.

GRADER SCORING SHEET

	Weight Rating	A-C	Cat.	Rome	A-W	Adams
Blade Opr.	6					
Engine Starting	3					
Transmission Shift	5					
Opr. of Controls	6					
Breakdowns	4					
Availability of Parts	4					
Maint. Nec. to Opr.	1					
Walking Speeds	3					
Maneuverability of Machine	5					
Safety - Brakes	7					
Visibility	5					
Controls Shift	6					
Opr. Fatigue	5					
Opr. Training Necessary	1					
Dip Const. & Maint.	8					
Ditching	5					
Drifting	3					
Bank Sloping	2					
Scarifying	5					
Move Windrow	6					
Remove Slides	6					
Road Maint.	8					
Fine Grading	2					

The eight forms were converted to final rating in percent and are tabulated below:

RATING TABLE

Individual	Grader A	Grader B	Grader C	Grader D	Cat #12
1	28.8	62.8	68.0	50.8	59.0
2	30.0	51.0	64.7	48.0	62.4
3	28.2	73.5	65.4	39.2	41.7
4	68.1	91.9	91.0	75.3	89.6
5	25.2	80.2	58.5	38.8	52.8
6	31.7	67.9	67.1	44.0	66.4
7	43.7	77.8	73.0	58.0	65.8
8	20.5	47.4	36.1	26.8	66.1
Average	34.5	69.1	65.5	47.6	63.0

It is significant that in all the ratings, Graders A and D held the positions of fourth and fifth respectively without transposition and by a substantial margin. Graders B and C changed from their averaged relative position three times, while the Cat #12 changed only twice.

It is evident from the ratings that the consensus of the observers as mentioned several times in the body of the report, can be substantiated, and is listed as follows:

Grader B	-	Most often	-	First
Grader C	-	Most often	-	Second
Cat #12	-	Most often	-	Third
Grader D	-	Definitely	-	Fourth
Grader A	-	Definitely	-	Fifth

If further deduction from the table were permitted, and if the sample of eight men could be taken as a cross-section of the entire field, it could be concluded that Grader B is the most desirable for overall Forest Service work, with Grader C and Cat #12 as acceptable alternates. Because of their relative low rating, Graders D and A would, be classed as undesirable.

Finally it could be said that even though Grader B was rated the highest, according to the table and comparison with the ultimate in graders for Forest Service Work, it was only 69.1 % effective.

AAA DETONATOR BRAKE TESTER

The electrically operated detonator brake tester, shown in photograph, Fig. A, is used to measure the effectiveness of equipment brakes. Mounted on the machine being tested, it is operated by two switches - the first controlled by an observer and the second mounted on the brake pedal.

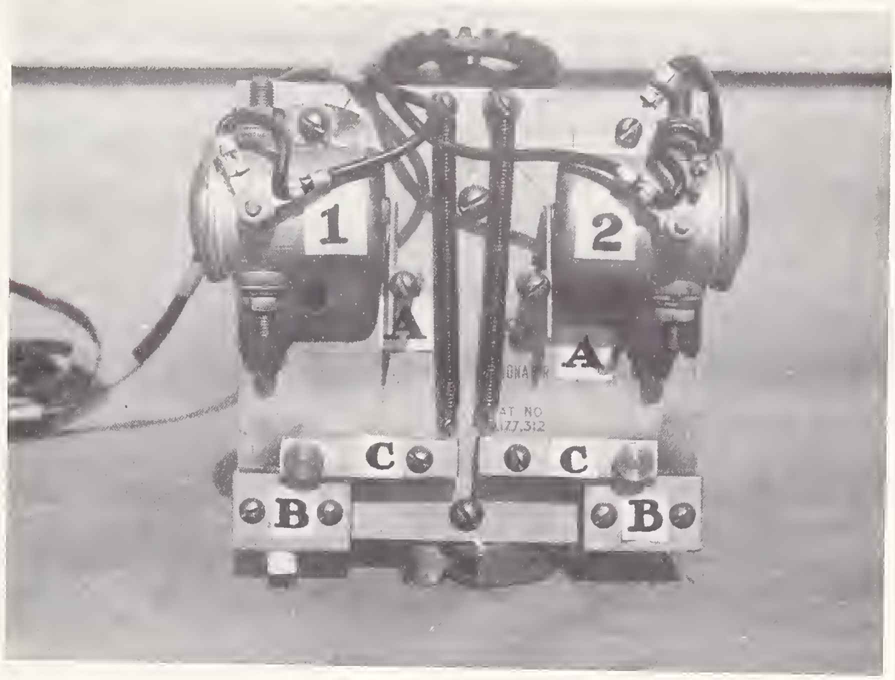


Fig. A. AAA Detonator Brake Tester

With the machine moving at the predetermined test speed, the observer operates the switch that releases solenoid 1 and allows its spring loaded hammer C to fire a blank cartridge in the block B. The force of the explosion expels chalk in the block and makes a mark on the pavement. On hearing the shot, the operator hits the brakes, causing the brake switch to release Solenoid 2, which fires a second piece of chalk to the pavement. When the machine comes to a complete stop a third chalk mark is made on the pavement directly under the detonator firing blocks.

The distance between the first and second shalk marks is measured and, since the speed of travel is known, can be converted into operator reaction time. The measurement between the second and third marks is the distance required to bring the vehicle to a stop at the given speed.

A complete description of the operation and use of this brake tester is available at the Arcadia Equipment Development Center, 701 N. Santa Anita Ave., Arcadia, California.